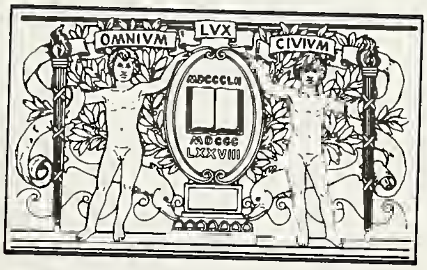
BOSTON PUBLIC LIBRARY
3 9999 06543 433 2

GOVDOC
BRA
5128



BOSTON
PUBLIC
LIBRARY

GOVDOC
BRA
5728

COPLEY PLACE

NOISE LEVELS REPORT

BOSTON
PUBLIC
LIBRARY

Property of
BOSTON REDEVELOPMENT AUTHORITY
Library

AY
N

H M M ASSOCIATES, INC.

BA
H1

Property of
BOSTON REDEVELOPMENT AUTHORITY
Library

COPLEY PLACE

NOISE LEVELS REPORT

December 1979

Prepared for

URBAN INVESTMENT AND DEVELOPMENT COMPANY
200 Clarendon Street
Boston, Massachusetts 02116

Prepared by

HMM ASSOCIATES, INC.
One Forbes Road
Lexington, Massachusetts 02173

#112 A.N

hmm HMM ASSOCIATES, INC.

Digitized by the Internet Archive
in 2012 with funding from
Boston Public Library

http://www.archive.org/details/copleyplacenoise00urba

TABLE OF CONTENTS

	Page
LIST OF FIGURES	v
LIST OF TABLES	vi
1. INTRODUCTION	1
1.1 Common Measures of Community Noise	2
1.2 General Characteristics of Community Noise	4
2. MEASURED NOISE LEVELS	7
2.1 Noise Receptors and Sources	7
2.2 Measured Noise Levels	8
• 1978 Spot Check Study	8
• 1979 24-hour Study	13
2.3 Significance of Measured Noise Levels	18
• Typical Noise Levels	18
• Government Noise Criteria	23
3. EXISTING CASE NOISE MODEL	25
3.1 Description of Receptors Modeled	25
• Model #1	25
• Model #2	26
3.2 Description of Noise Modeling Procedure	26
• Traffic Noise Model	27
• Rail Noise Model	34
• Background Noise	41
3.3 Existing Noise Model Results	41
4. CONSTRUCTION PHASE NOISE LEVELS	44
4.1 Inputs to the Construction Noise Model	44
• Construction Equipment Schedules	44
• Construction Equipment Location	44
• Construction Equipment Noise Emission Characteristics	44
4.2 Construction Noise Model	50
4.3 Construction Noise Model Results	53
• Receptor #1, Gloucester Apartments	53
• Receptor #2, Copley Square	53
• Receptor #3, Dartmouth Street	53

TABLE OF CONTENTS (Continued)

Page

- Receptor #4, Tent City 54
- Receptor #5, Harcourt Street 54
- Receptor #6, Mini-Pru 54
- SW Corridor Project Construction 54

5. OPERATIONAL NOISE LEVELS (1983) 56

5.1 Causes of Future Noise Impacts 56

5.2 Future Noise Level Models 58

- Traffic and Rail 58
- Background 61
- HVAC 61

5.3 Future Noise Model Results 62

5.4 Significance of Noise Impacts 65

APPENDIX A BACKGROUND NOISE INFORMATION

APPENDIX B DESCRIPTION OF 24-HOUR NOISE MONITORING PROCEDURE

APPENDIX C HUD REGULATIONS

APPENDIX D TRAFFIC MODEL

1. Copy of FHWA Model
2. Worksheets

APPENDIX E RAIL NOISE CALCULATIONS

APPENDIX F CONSTRUCTION EQUIPMENT SCHEDULE

APPENDIX G CONSTRUCTION NOISE CALCULATIONS FOR EACH RECEPTOR

APPENDIX H FUTURE-CASE TRAFFIC MODELS

APPENDIX I HVAC EQUIPMENT MODEL

LIST OF FIGURES

Figure

1.1 - Graphical Representation of Equivalent Noise (L_{eq})
1.2 - Typical Range of Common Sounds
2.1 - 1978/1979 Copley Place Noise Monitoring Locations
2.2 - Diurnal Variation in Noise Levels at Harcourt Street
2.3 - Examples of Outdoor Day-Night Average Sound Levels
2.4 - Noise Monitoring Sites, City of Boston, 1975
3.1 - Existing Noise Model #1
3.2 - Existing Noise Model #2
3.3 - Angle Identification of Roadway Segments
3.4 - Location of Rail Noise Components
4.1 - Construction Schedule
4.2 - Theoretical Construction Activity Site Centers
5.1 - Schematic Locations of HVAC Equipment

LIST OF TABLES

Table

1.1 Common Noise Levels
2.1 Description of Noise Monitoring Locations
2.2 Summary of "A"-Weighted Measurement Data, 1978
2.3 Existing Noise Levels
2.4 24-Hour Noise Measurements
2.5 L_{eq24} and L_{dn} Calculations
2.6 Residual Noise Levels in Residential Areas
2.7 Existing Noise Levels in the Back Bay, Boston
2.8 Noise Exposure Levels Safe for Human Hearing
3.1 Distances Between Receptors and Links (Meters)
3.2 Existing Traffic Volumes and Speeds
3.3 Traffic Noise Emission, Model #1
3.4 Traffic Noise Emission, Model #2
3.5 Rail Noise Emission
3.6 Calculation of Background Noise
3.7 Noise Model Summary
4.1 Construction Equipment Noise Emission Characteristics
4.2 Calculated Approximate Peak L_{eq} for Construction Equipment
4.3 Summary of Construction Phase Noise Levels
4.4 Summary of City of Boston Construction Noise Regulations
5.1 Traffic Noise Emissions, Future Case Model #1
5.2 Traffic Noise Emissions, Future Case Model #2
5.3 Vent Noise Component
5.4 Predicted Noise Levels (L_{eq})
5.5 Boston Noise Standards by Zone

1. INTRODUCTION

This report has been prepared for the Urban Investment and Development Company, the proponent of the Copley Place development located in Boston, Massachusetts. It documents the procedures and conclusions of the noise studies relating to the proposed project. This document presents analyses of:

- Measured noise levels near the site;
- Contributions to measured noise levels modeled by component;
- Construction noise impacts;
- Operational noise impacts; and
- Relevant noise level criteria.

These analyses are based on the following sources of data:

- 1978 noise measurements presented in the 1978 Draft EIR for Copley Place;
- A 24-hour noise monitoring program undertaken adjacent to the Copley Place site in 1979;
- The most recent traffic data available*;
- Best available construction schedule scenarios; and
- Current design of HVAC vents and barrier configurations.

All raw data, models, and calculations are presented in the appendices to this report. The procedures and findings presented in the body of this report are included in condensed form in the 1979 Draft EIR Supplement/Draft EIS for Copley Place.

---

*Copley Place Transportation Impacts Study, PBQD/NAA, October 1979.

1.1 Common Measures of Community Noise

When assessing the impact of noise on people, background levels, noise peaks, and the fluctuation of the noise levels are generally considered. Non-steady noise exposures in the community are commonly expressed in terms of an A-weighted sound level (dBA) that is exceeded for a percentage of the measured time period. The term "L_x" is used to describe the sound level value that is exceeded for x percent of the time period under consideration. Following are some of the commonly used "percentile levels":

L_{10} = The noise level (dBA) that is exceeded 10% of the time. L_{10} of 70 dBA due to peak-hour traffic noise is the maximum design level criteria for residentially zoned areas (including hospitals) used in the Federal Highway Administration noise standards.

L_{50} = The median noise level value. Half of the observed measurements exceed L_{50} during a given sampling period.

L_{90} = The noise level that is exceeded 90% of the time. L_{90} is used as a measure of background noise.

Another method of quantifying the noise environment is to determine the value of steady-state sound which has the same A-weighted sound energy as that contained in the time-varying sound. This is termed the Equivalent Sound Level (L_{eq}). It is graphically depicted in Figure 1.1. The L_{eq} is a single value of sound level for any desired duration, which includes all of the time-varying sound energy in the measurement period. The major virtue of the L_{eq} is that it correlates reasonably well with the effect of noise on people, even for wide variations in environmental sound levels and time patterns. It is used when only the durations and levels of sound, and not their times of occurrence (day or night), are relevant.

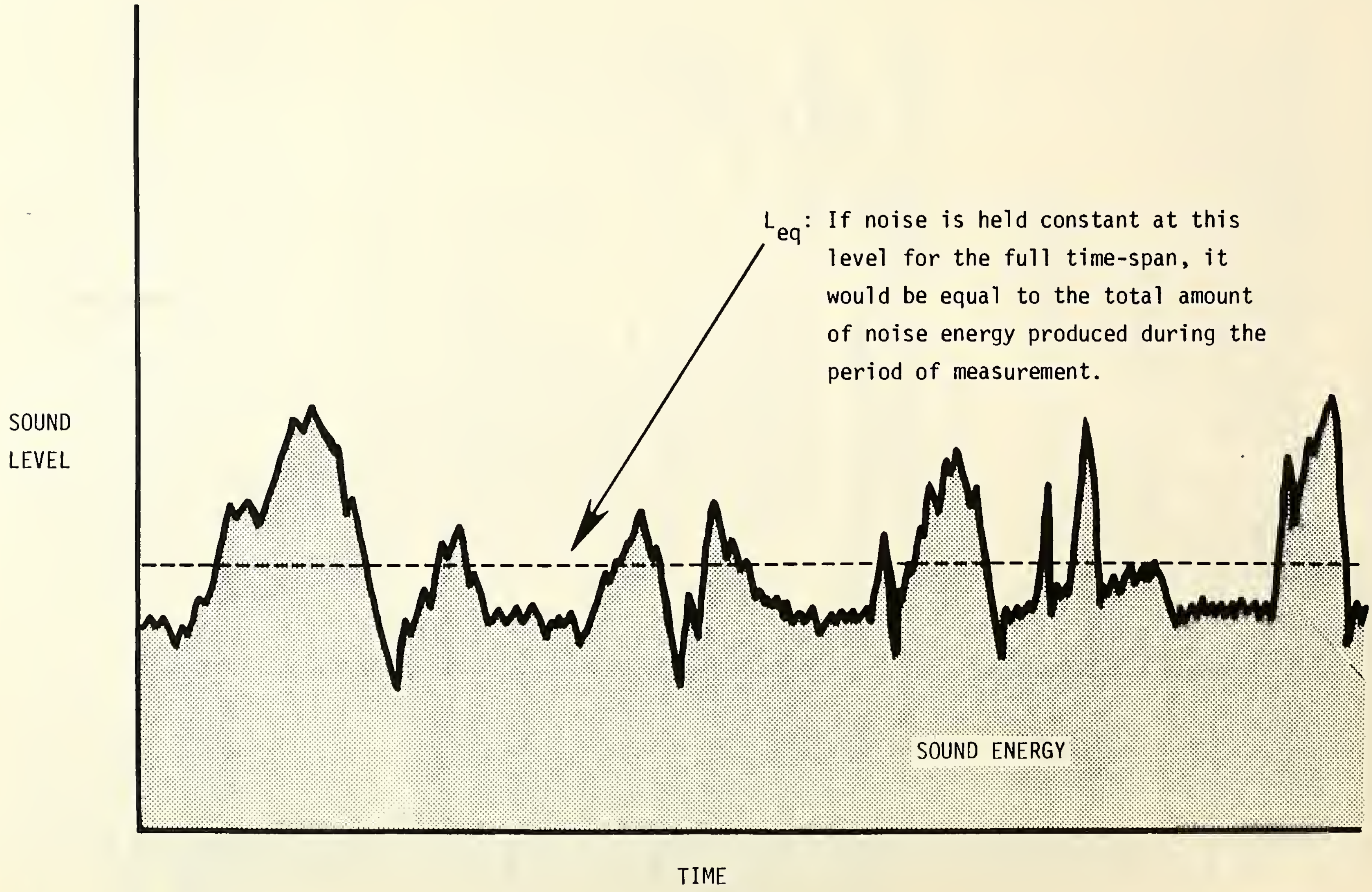


FIGURE 1.1 - GRAPHICAL REPRESENTATION OF EQUIVALENT NOISE LEVEL

The day/night equivalent noise level (L_{dn}) is another measure for describing environmental noise exposure. This is the L_{eq} for a 24-hour period, with an additional 10 dBA weighting added to the nighttime noise levels (10:00 PM - 7:00 AM). L_{dn} and L_{eq} are the noise values used by HUD and EPA in their acceptability criteria.

1.2 General Characteristics of Community Noise

The noise environment of a typical urban community contains a nearly steady "background" noise resulting from industrial noise, commercial activity, heating and air conditioning equipment, other continuously operating machinery, and the multitude of motor vehicles throughout the city. Superimposed on the background is the noise from nearby cars, trucks, trains, planes, and noise from the general activity of people. Table 1.1 identifies noise levels associated with some common activities and sources of noise.

Sound ranges associated with common activities are presented in Figure 1.2.

Additional information about measures of sound and typical levels is presented in Appendix A.

TABLE 1.1

COMMON NOISE LEVELS

Sound Level (dBA)	Associated Activity
130	Threshold of Pain
120	Chipping on Metal
110	Rock Band
100	Jack Hammer
	Jet Take-off (1/2 mile)
90	Threshold of Hearing Damage
80	Shop in Shipyards
	Busy Freeway
70	Downtown Traffic
	Electric Typewriter
60	Normal Conversation
	Urban Residential Area (Nearby Traffic)
50	Drafting Office
40	Suburban Neighborhood(Distant Traffic)
	Private Office
30	
20	Quiet Rural Area (No Traffic)
10	
0	Threshold of Audibility

Adapted from Acoustical Seminar, Robin M. Towne & Associates, 1971. (These values are approximate, and do not reflect specific situations described in this report.)

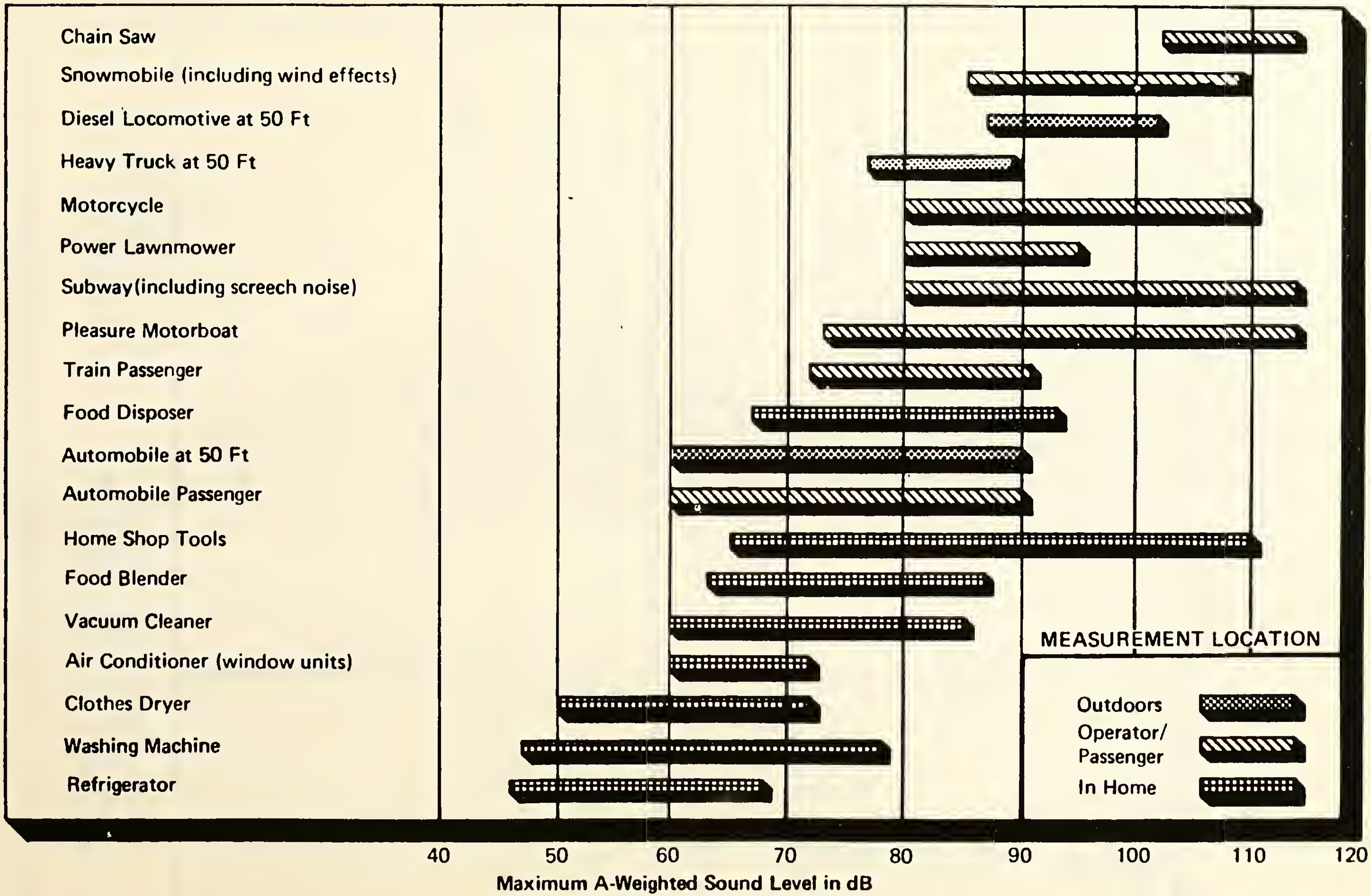


FIGURE 1.2 - TYPICAL RANGE OF COMMON SOUNDS

2. MEASURED NOISE LEVELS

2.1 Noise Receptors and Sources

The noise study undertaken for the Copley Place project was designed to measure noise levels at representative locations surrounding the site. An attempt was made to characterize the various types of noise sources and receptors near the site. Noise monitoring sites were chosen at locations surrounding the site. Each site reflects proximity to selected noise sensitive receptors. Noise sensitive receptors identified in the Copley Place vicinity include residences, hotels, churches, public open areas, and the Boston Public Library.

During the measurement programs, four primary sources of local noise were apparent:

1) Local Traffic. Noise levels generated by trucks, cars, and buses on the local street system are clearly evident in the area. The Turnpike is the largest local carrier of motor vehicles. Its impact on ambient noise levels in the area, however, is reduced by the fact that it is in a depressed section throughout the study area, and covered by both the Prudential Center and the Hancock garage immediately adjacent to the site. Huntington Avenue, Dartmouth Street, Boylston Street, Stuart Street, and Columbus Avenue are all urban arterial streets which carry reasonably large traffic volumes.

2) Existing Public Transportation Facilities. The site abuts the AMTRAK line on one side and is crossed by the B & A rail line. Rail activity contributes significantly to local noise levels at certain times of the day.

3) HVAC Noise. Many of the buildings in the area have substantial HVAC plants. These systems contribute mechanical and air-vent noise to the background noise levels.

4) Background Noise. Nearby businesses including a printing shop, retail stores, restaurants, and garages contribute background noise levels. In addition, overflights by aircraft contribute to local noise levels.

The six noise monitoring locations are shown on Figure 2.1. Table 2.1 summarizes the receptors and local noise sources which contribute to the levels recorded at each monitoring location.

2.2 Measured Noise Levels

Two noise measurement studies have been undertaken in the Copley Place project area. In 1978, a series of 48 "spot-checks" was made by ERT for use in the Copley Place Draft EIR. In response to community concern and Federal HUD requirements, a second, 24-hour noise measurement was conducted by HMM in August, 1979, for the Draft EIR Supplement/Draft EIS for Copley Place.

1978 Spot-Check Study

During the period from August 16 through August 24, 1978, a series of 48 short-term noise measurements were taken at the six locations shown on Figure 2.1. Measurement times were selected to reflect the quietest hours (early weekend mornings) and typical business hours. Table 2.2 presents all of the A-weighted noise level data for each monitoring station. Table 2.3 shows the maximum and minimum measured and estimated L_{eq} levels at each of the six measurement sites. In most cases, spot-check noise measurements were not taken during the hours of peak noise level (7:00 - 8:00 AM and 5:00-6:00 PM)

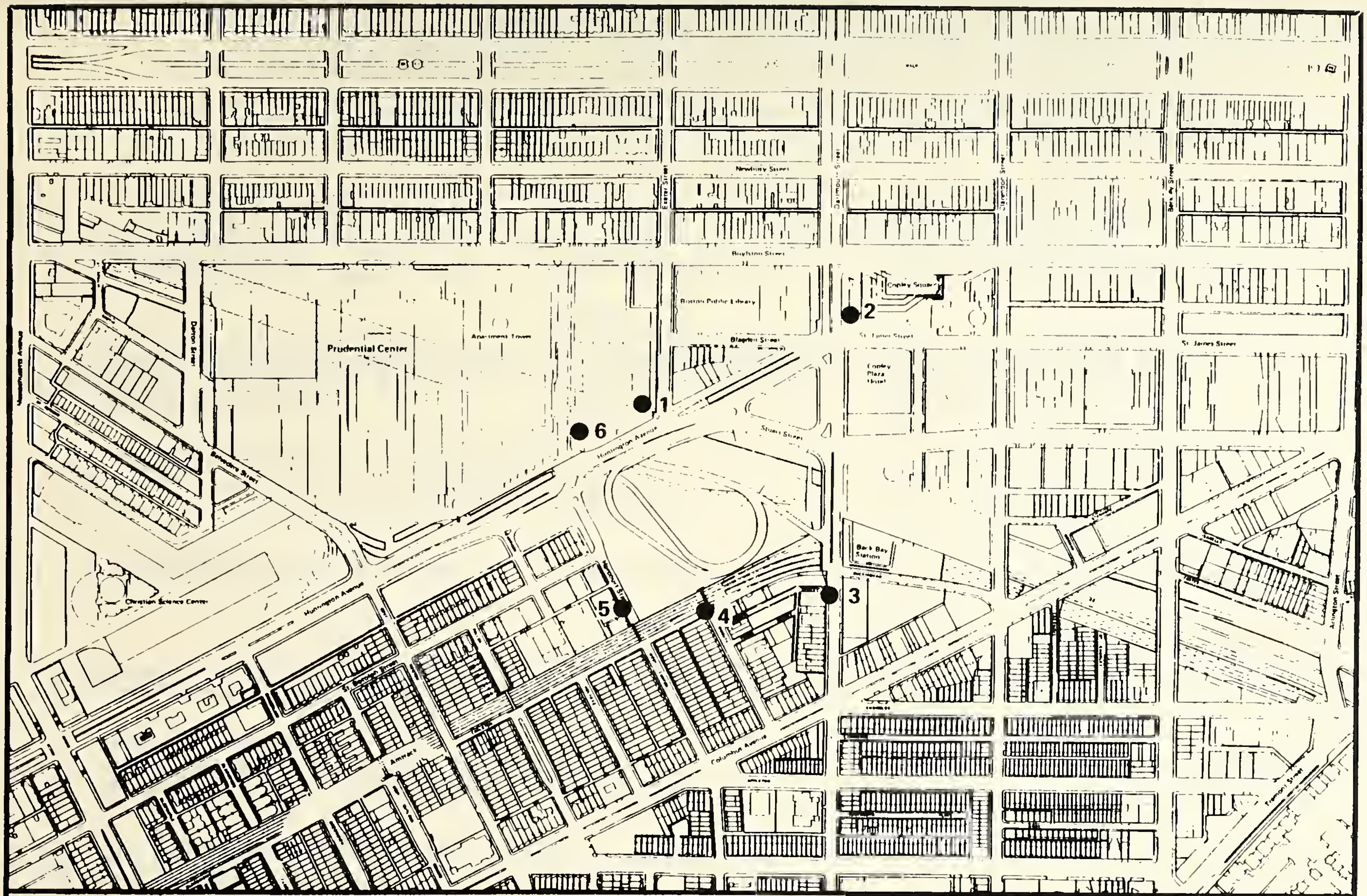


FIGURE 2.1 - 1978/1979 COPLEY PLACE NOISE MONITORING LOCATIONS

TABLE 2.1

Site No.	Site Location Description	Receptor	Main Noise Source
1	20 ft. from Gloucester apartment building in Prudential Center complex	Residences	Traffic on Huntington Avenue & Exeter Street, commercial activity
2	Southwest corner of Copley Square	Boston Public Library Trinity Church Copley Square	Traffic on Boylston, Stuart, Dartmouth Streets, heavy commercial activity, pike-bound traffic
3	Dartmouth Street adjacent to Community Garden	Community Garden	Pike & Back Bay-bound traffic on Dartmouth Street, train traffic
4	Adjacent to Tent City parcel at the corner of Yarmouth and Carleton Streets - neighborhood	Residences	Train traffic Local traffic
5	Harcourt Street across from Bethel Revival Center, primarily commercial land-use along street	Offices Residences - location of planned housing component of Copley Place	Trains Local traffic Ramp traffic from pike
6	Near Mini-Pru, 60 feet off Huntington Avenue	Office building	Traffic on Huntington Avenue Pike ramps Commercial activity

TABLE 2.2

SUMMARY OF "A"-WEIGHTED MEASUREMENT DATA, 1978

Location	Date	Time	"A"-Weighted Noise Level Statistics L_{99}	L_{90}	L_{50}	L_{10}	L_{eq}
1	8/16/78	1414	58	60	61	65	63
	8/17/78	0338	53	54	55	58	56
	8/19/78	0451	53	53	55	57	56
		0715	53	53	54	57	56
	8/20/78	0430	50	51	52	55	54
		0717	52	53	56	60	58
	8/23/78	2231	55	56	57	59	59
	8/24/78	0955	61	62	64	67	66
2	8/16/78	1613	63	63	66	70	69
	8/17/78	0515	56	57	58	62	62
	8/19/78	0639	53	54	56	60	59
		0853	55	57	60	64	63
	8/20/78	0629	54	55	56	62	63
		0907	54	55	59	65	64
	8/24/78	0017	55	57	59	63	61
		1144	60	62	64	69	67
3	8/16/78	1542	57	58	61	67	65
	8/17/78	0501	52	53	54	59	57
	8/19/78	0612	50	51	53	58	57
		0838	54	55	58	62	61
	8/20/78	0601	51	51	52	56	54
		0841	52	53	57	61	60
	8/23/78	2353	53	54	57	62	60
	8/24/78	1119	56	58	61	66	66
4	8/16/78	1526	53	54	55	63	61
	8/17/78	0436	51	52	53	55	55
	8/19/78	0559	50	50	51	54	53
		0814	53	53	55	58	57
	8/20/78	0545	49	50	51	52	52
		0825	50	51	52	54	53
	8/23/78	2338	51	53	54	56	55
	8/24/78	1105	55	56	58	62	61
5	8/16/78	1500	60	60	61	62	62
	8/17/78	0421	58	59	59	59	60
	8/19/78	0533	57	58	58	59	59
		0758	54	55	60	63	61
	8/20/78	0515	50	50	51	52	52
		0759	50	51	53	58	56
	8/23/78	2313	53	54	59	62	60
	8/24/78	1040	58	59	60	62	62
6	8/16/78	1441	56	57	59	61	60
	8/17/78	0354	52	53	54	56	55
	8/19/78	0515	50	51	53	56	55
		0730	52	53	54	56	56
	8/20/78	0456	50	51	52	54	54
		0743	52	53	56	62	60
	8/23/78	2256	54	54	56	58	57
	8/24/78	1021	60	60	62	64	63

Source: ERT Field Monitoring Program 8/16,17,19,23 and 24/1978/

TABLE 2.3

EXISTING NOISE LEVELS

Location	Maximum Observed L_{EQ}	Estimated Maximum L_{EQ}	Minimum Observed L_{EQ}	Estimated Minimum L_{EQ}
Site #1				
Gloucester Apartments	66	69	54	54
Site #2				
Copley Square	66	67	59	57
Site #3				
Dartmouth Street	66	72	54	53
Site #4				
Tent City	61	70	52	52
Site #5*				
Harcourt	69	69	52	52
Site #6				
Mini-Pru	63	66	54	54

*The observed maximum and minimum L_{eq} at Site #5 reflects noise levels measured in the 24-hour study made at that location.

determined in the 24-hour study (see next section) In order to estimate the peak noise levels at each receptor, an assessment was made of the traffic and rail noise inputs at each one. In addition, the noise measurement times were compared to the diurnal variation measured at Harcourt Street. For those receptors located adjacent to loud commuter noise sources, such as the Mass Pike and rail lines , a strong rush-hour noise peak was assumed. For sites further from these noise sources, a less pronounced peak was assumed. Minimum measured noise levels were recorded at times that corresponded fairly wlll with the diurnal low-point. Only two of the estimates are lower than the recorded minimum L_{eq}.

The maximum estimated L_{eq} levels range from 72 dBA, at location #3, to 66 dBA, at location #6. L_{eq} levels are higher at the locations closer to the railroad tracks and the turnpike ramps where heavy commuter traffic has the most significant input to noise levels.

The minimum L_{eq} ranges from 52 dBA to 57 dBA; approximately 15 dBA below the maximum noise levels.

1979 24-hour Study

A 24-hour, round-the-clock, noise monitoring program was conducted at monitoring location #5 on Harcourt Street in August of 1979. This study was conducted in response to expressed community concern as well as Federal HUD requirements. Through this study, diurnal variation in noise levels was documented. As explained, this information was used in estimating peak noise levels at the other five monitoring sites. L_{eq24} and L_{dn} were calculated using these results as well.

Harcourt Street was chosen as the site for this study for several reasons. For one, it is nearest to the location of the planned residential component of the Copley Place project, and therefore, the best place to determine the noise levels governed by HUD new housing regulations. In addition, it is near two major noise sources; turnpike ramps and rail line. Further, the location is in an existing residential zone and can be compared to other typical residential noise levels.

The 24-hour study was carried out using a GenRad 1945 Community Noise Analyzer, a 1/2 inch microphone with a windscreen and pre-amp. The equipment was calibrated at the beginning of each run, with a GenRad 1987 minical sound level calibrator.

The GenRad 1945 Noise Meter records 16 noise level parameters, described in Appendix B. Measurements were taken for hour-long intervals during the day, and longer ones at night (22:00 to 24:00 and 24:00 to 6:00). For a more detailed description of the procedure used, see Appendix B.

The results of this monitoring program are presented in Table 2.4. From these measurements, a graph showing the diurnal variation in noise level was constructed. Figure 2.2 shows the profile of L_{eq} and L_{90} levels at Harcourt Street. The measured noise levels rose sharply during commuter rush-hour traffic periods; peaking during the 7:00 to 8:00 AM and 5:00 - 6:00 PM hours. A lull in noise levels is apparent during the afternoon. The lowest noise levels occur during the nighttime hours.

The measured noise levels at this location reflect heavy traffic on the turnpike ramps, nearby rail noise, airplanes passing overhead, traffic in the surrounding street network, and occasional cars and trucks on Harcourt Street.

The average L_{eq} for the entire 24 hours (L_{eq24}), as measured at site #5 on Harcourt Street, was calcualted to be 62.9 dBA. The corresponding L_{dn} is equal to 66.7 dBA. These calculations are presented in Table 2.5.

TABLE 2.4

24-HOUR NOISE MEASUREMENTS

Hour (Beginning)	L_{eq}	L_{90}
8:00	63	59
9:00	64	58
10:00	62	56
11:00	63	53
12:00	61	54
13:00	62	54
14:00	60	54
15:00	60	55
16:00	68	60
17:00	69	60
18:00	67	58
19:00	64	56
20:00	61	53
21:00	64	52
22:00-24:00	61	55
24:00- 6:00	61 }n	51 }n
6:00	65	60
7:00	69	62

$L_{eq\ 24}$ = 62.9 dBA

L_{dn} = 66.65 dBA

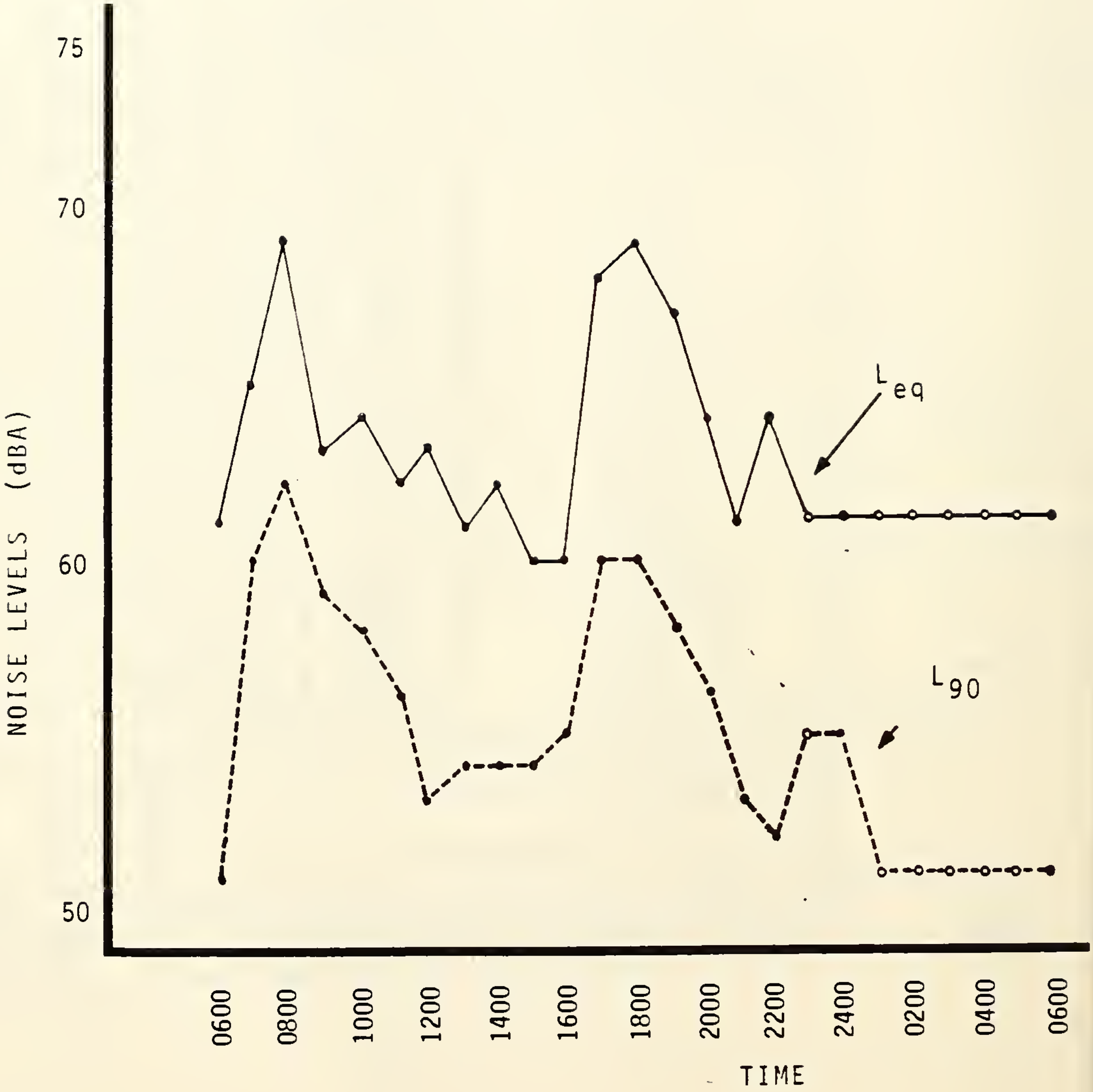


FIGURE 2.2 - DIURNAL VARIATION IN NOISE LEVELS AT HARCOURT STREET

TABLE 2.5

L_{eq24} AND L_{dn} CALCULATIONS

$$L_{eq\ day} \quad 7{:}00\text{-}22{:}00 = \frac{(63+64+62+63+61+62+60+60+68+69+67+64+61+64+69)}{15}$$

$$= \frac{957}{15} = \boxed{63.8\ \text{dBA}}$$

$$L_{eq\ night} \quad 22{:}00\text{-}7{:}00 = \frac{2(61)+6(61)+65}{9} = \frac{553}{9} = \boxed{61.4\ \text{dBA}}$$

$$L_{eq\ 24} = \frac{15(63.8 + 9(61.4)}{24} = \boxed{62.9\ \text{dBA}}$$

$$L_{eq\ dn} = \frac{15(63.8) + 9(61.4 + 10)}{24} = \boxed{66.65\ \text{dBA}}$$

2.3 Significance of Measured Noise Levels

These measured noise levels are significant both in terms of their relation to other typical noise levels and government noise criteria:

Typical Noise Levels

Table 2.6 lists some background noise levels which the EPA considers typical of various neighborhoods. The average daytime L_{90} for the Copley Place site (from the 24-hour study) is 56.3 dBA. This means that the site for the new housing component of the project lies in a "very noisy urban residential" area. As shown in Figure 2.3, based on L_{dn}, EPA states that the site is typical of "urban row housing on a major avenue."*

Figure 2.4 shows noise monitoring locations used in a study by the Boston Air Pollution Control Commission in 1975. Table 2.7, shows noise levels measured at these locations. The average of all locations is compared to noise levels recorded during the 24-hour monitoring program at Harcourt Street. The peak L_{90} value at Harcourt Street is the same as the average for the six sites in the Back Bay study. The average peak L_{eq} in the Back Bay study is 73 dBA, 4 dBA higher than the 69 dBA measured at Harcourt Street. The difference in these values may be attributed largely to the very high peak L_{eq} levels at sites BB-4, Dartmouth Street, where it passes over the Mass. Pike. and BB-6, Boylston Street. Average L_{eq24} and L_{dn} values for Back Bay are higher than those measured on Harcourt Street. Furthermore, not a single measurement at any one of the Back Bay locations is as low as those measured on Harcourt Street. This difference is principally due to the larger volume of traffic, pedestrians, and commercial activity in immediate proximity to the noise monitoring locations selected by the Boston Air Pollution Control Commission. The commission sites are closer to such noise sources than the Harcourt Street monitor, which is somewhat removed from the major traffic routes.

---

*EPA, Protective Noise Levels - Condensed Version of EPA Levels Document, November 1978, EPA 550/9-79-100, Pg. 8.

TABLE 2.6

QUALITATIVE DESCRIPTORS OF URBAN AND SUBURBAN DETACHED HOUSING RESIDENTIAL AREAS AND APPROXIMATE DAYTIME RESIDUAL NOISE LEVEL (L_{90})

Description	Daytime Residual Noise Level in dBA	
	Typical Range	Average
Quiet Suburban Residential	36 to 40 inclusive	38
Normal Suburban Residential	41 to 45 inclusive	43
Urban Residential	46 to 50 inclusive	48
Noisy Urban Residential	51 to 55 inclusive	53
Very Noisy Urban Residential	56 to 60 inclusive	58

Source: Community Noise, December 31, 1971 United States Environmental Protection Agency (page 28, Table 5).

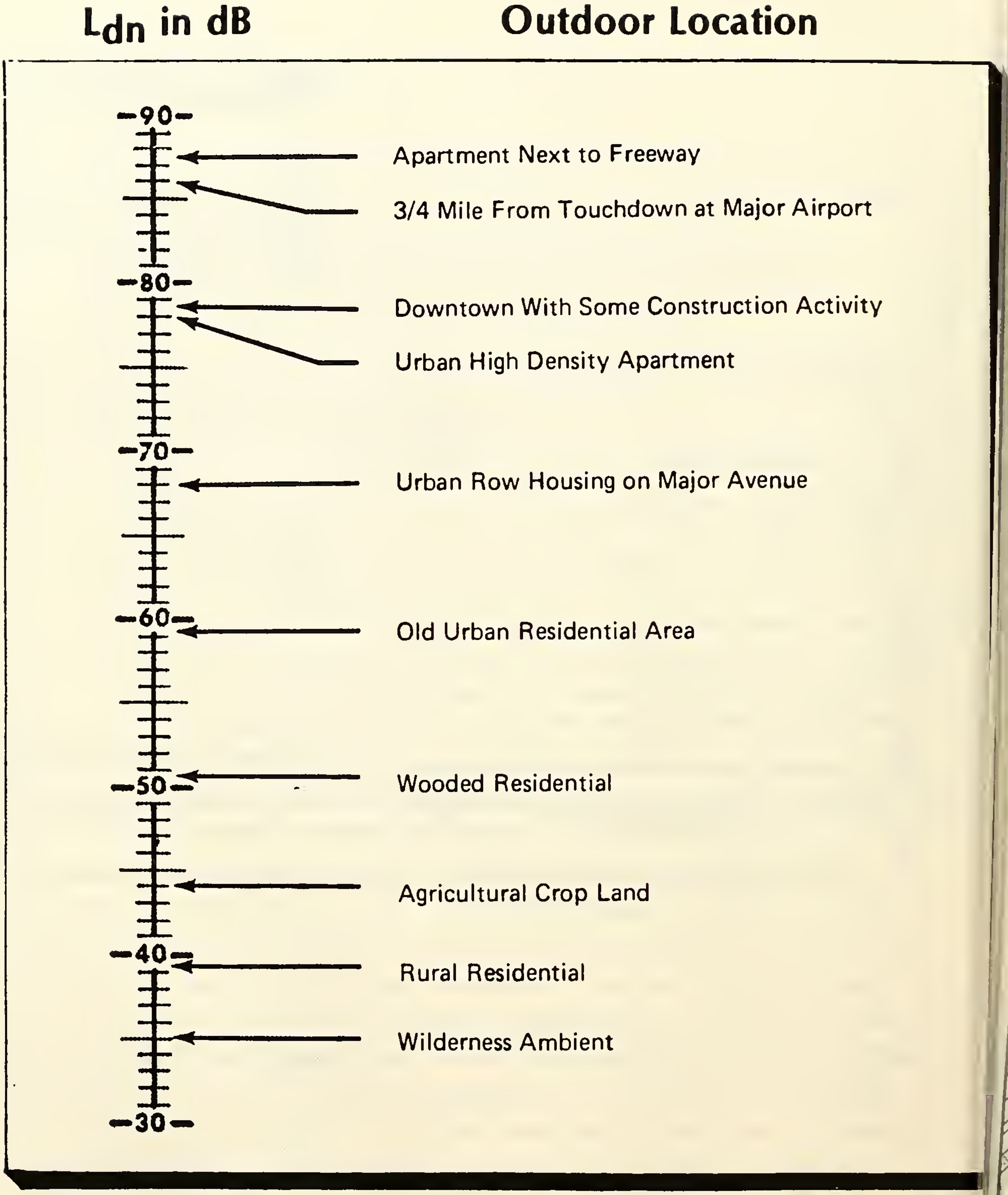


FIGURE 2.3 - EXAMPLES OF OUTDOOR DAY-NIGHT AVERAGE SOUND LEVELS IN dB MEASURED AT VARIOUS LOCATIONS

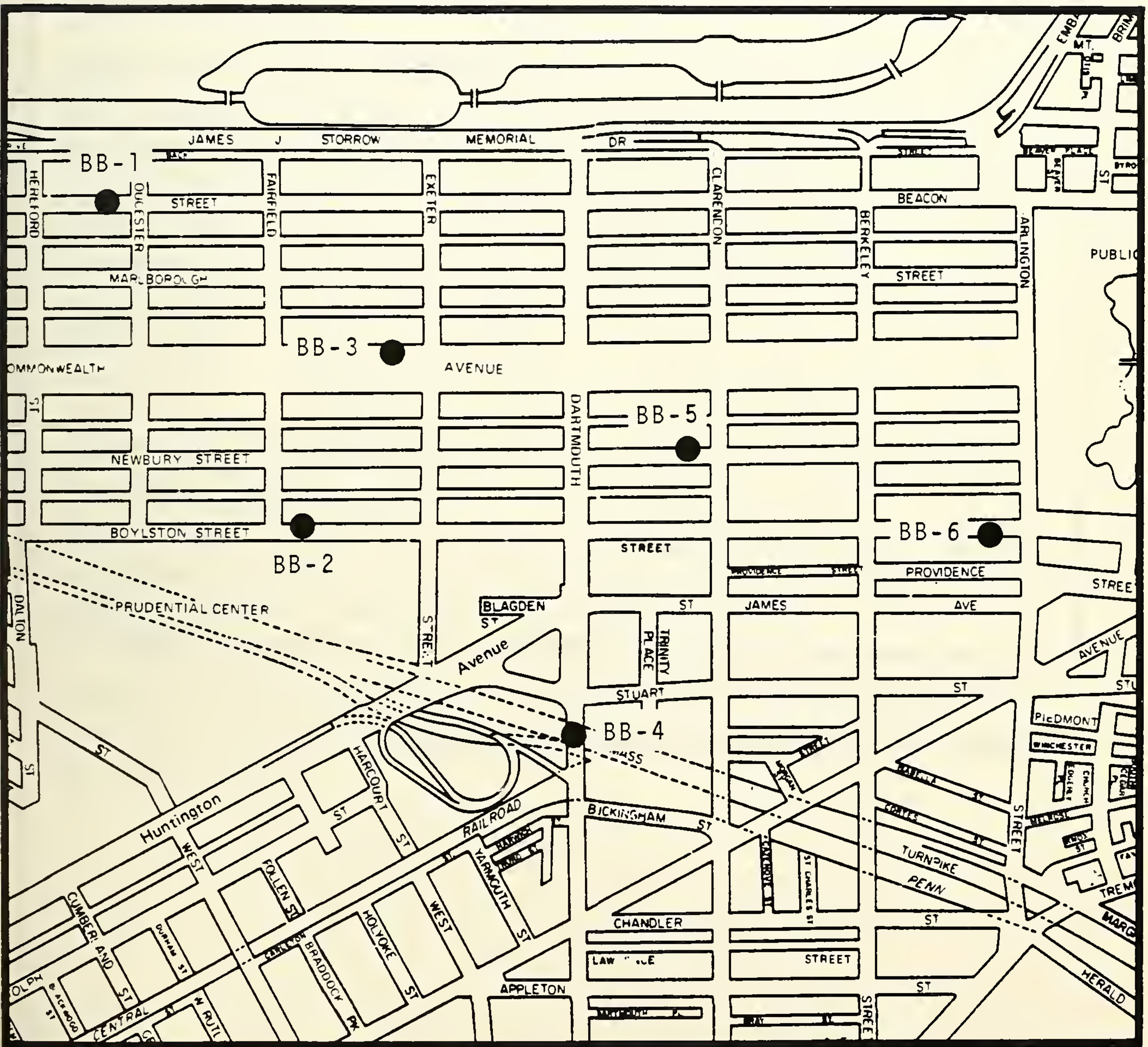


FIGURE 2.4 - NOISE MONITORING SITES, CITY OF BOSTON, 1975

TABLE 2.7

EXISTING NOISE LEVELS (dBA) IN THE BACK BAY, BOSTON

Site No.	Location	Peak L_{eq}	Peak L_{90}	L_{eq24}	L_{dn}
BB-1	413 Beacon St.	67.8	57	65.5	70.7
BB-2	799 Boylston St.	71.5	63	68.8	73.8
BB-3	203 Commonwealth Ave.	73.0	58	67.8	72.1
BB-4	Dartmouth St. at Bridge over Mass. Pike	79.9	69	73.9	75.5
BB-5	117 Newbury St.	66.1	60	63.8	68.4
BB-6	360 Boylston St.	78.1	65	75.2	84.0
	Average	72.7	62	69.2	74.1
Harcourt Street for Comparison		69	62	62.9	66.7

Source: City of Boston Noise Survey, 1975.

Government Noise Criteria

The EPA has published guidelines to protect public welfare and hearing. These guidelines, presented in Table 2.8, state that an acceptable level of noise, which will cause less than 5 dBA of hearing loss over 40 years, is 70 dBA (L_{eq24}). Since the L_{eq24} at the Copley site is 62.9 dBA, it is well below the level which could cause hearing loss due to noise.

The Department of Housing and Urban Development (HUD) has its own set of criteria to evaluate new housing which the agency funds. As of August 1979, HUD uses L_{dn} as a measure of noise level acceptability. The criteria are as follows:

L_{dn}	
Not exceeding 65 dBA	Acceptable
Between 65 dBA and 75 dBA	Normally Unacceptable
Above 75 dBA	Unacceptable

The current L_{dn} for Copley Place (66.7 dBA) is in the lower portion of HUD's "Normally Unacceptable" range.

HUD approvals in this zone would require a minimum of 5 decibels additional sound attenuation for buildings having noise sensitive uses. The complete HUD regulations are presented in Appendix C.

TABLE 2.8

NOISE EXPOSURE LEVELS SAFE FOR HUMAN HEARING*

		Steady (Continuous) Noise	Intermittent Noise	With Margin of Safety
L_{eq}, 8 hour	250 day/year	73	78	
	365 day/year	71.4	76.4	75
L_{eq}, 24 hour	250 day/year	68	73	
	365 day/year	66.4	71.4	70

*(At-Ear) exposure levels that produce no more than 5 dB noise-induced hearing damage over a 40-year period (L_{eq})

Source: EPA Levels document, condensed version.

3. EXISTING CASE NOISE MODEL

There were three major inputs into the noise model constructed for Copley Place; traffic, rail, and background noise. Separate models were constructed for traffic and rail components. The background noise was then determined and the three components added together.

All noise levels discussed in the noise model are measures of L_{eq}.

3.1 Description of Receptors Modeled

Two receptors were modeled for existing noise.

Model #1

Noise monitoring site #5 on Harcourt Street was chosen as the receptor for the first model. Reasons for choosing this site include:

- It was the location of the 24-hour study and could therefore yield an accurate background noise determination.
- It is the location where the new housing is planned.
- It is a site where a large change in noise level is anticipated. This is due to large noise contributions from noise sources which will be decked in the future.
- This site is representative of monitoring sites 3, Dartmouth Street, and 4, Tent City since these sites are also adjacent to rail and Massachusetts Turnpike noise sources.

Model 2

The second receptor location modeled was monitoring site #1, the corner of the Gloucester apartment building. This site was chosen for two main reasons:

- It is the location of an existing sensitive receptor; a residential apartment building.
- Noise levels at this location are not expected to change a great deal. This is because it is more distant from noise sources to be decked over, and amidst streets with a high level of local circulation and commercial activity. Future noise impacts at this site are considered to be representative of sites #2 at Copley Square and #6 at the mini-Pru. These monitoring locations are also somewhat removed from the major sources of noise to be decked and amidst local arterials and commercial activity.

3.2 Description of the Noise Modeling Procedure

As mentioned, noise levels near the Copley Place site were modeled in three components, i.e., traffic, rail, and background noise. The traffic noise inputs were determined by link using procedures outlined in the FHWA Highway Traffic Noise Prediction Model*. Rail noise was then added to this. Background noise was determined by subtracting the sum of rail and traffic noise from the peak measured noise levels.

---

*This model is contained in the U.S. Department of Transportation Federal Highway Administration report number FHWA-RD-77-108 dated December 1978. A copy of the model and worksheets are included in Appendix D.

Traffic Noise Model

In order to determine the contribution of traffic to existing local noise levels, a diagram of the traffic links was drawn. Traffic volumes and speeds were included. Information gathered from this diagram was input into the FHWA model to calculate the total traffic noise contribution. This process was done using the step-by-step procedure which follows.

1) Selection of Receptor Locations. Locations at which to determine noise levels were chosen. This choice reflected the goals of the study, sensitive receptor locations, availability of noise data at a location and other factors. The factors used in choosing the receptors for the Copley Place noise models are explained in Section 2.1 of this report.

2) Determination of Significant Links. The geography of the road network surrounding the receptor was studied. Roadway sections which appeared to have a significant noise input to noise levels at the receptor locations were included in the model. Geographical representations of the receptor and links used in the traffic models constructed for Copley Place are included in Figures 3.1 and 3.2.

3) Measurement of the Distance Between Each Receptor and Link. This is the perpendicular distance, in meters, between the centerline of the travel lane of each link and the receptor. When necessary, the centerline was extended to allow measurement of the perpendicular distance. In cases where the link extended away from the receptor, it was treated as a point source. The formula used for this calculation is included in Appendix D with the worksheets. These distances are presented in Table 3.1.

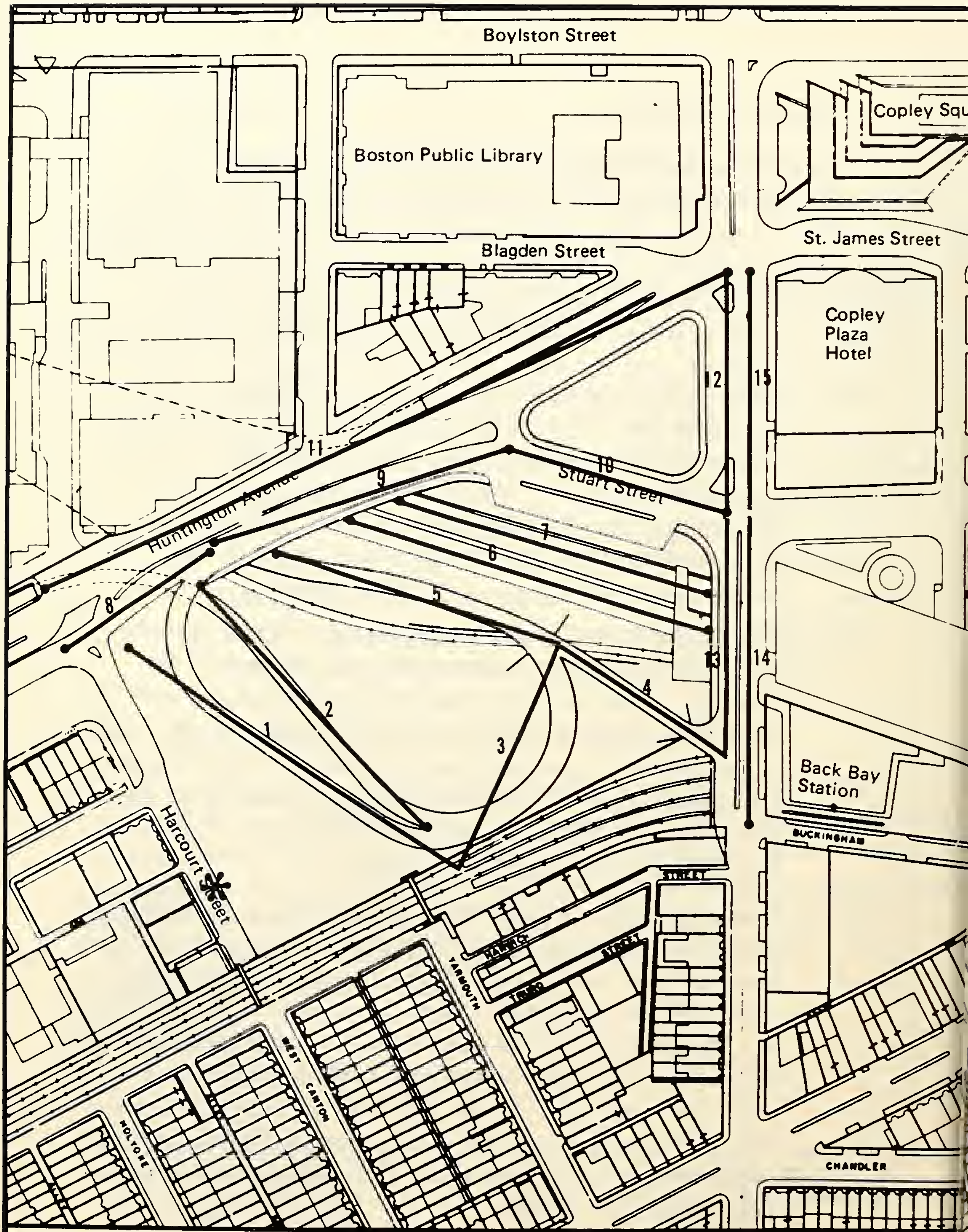


FIGURE 3.1 - EXISTING NOISE MODEL #1

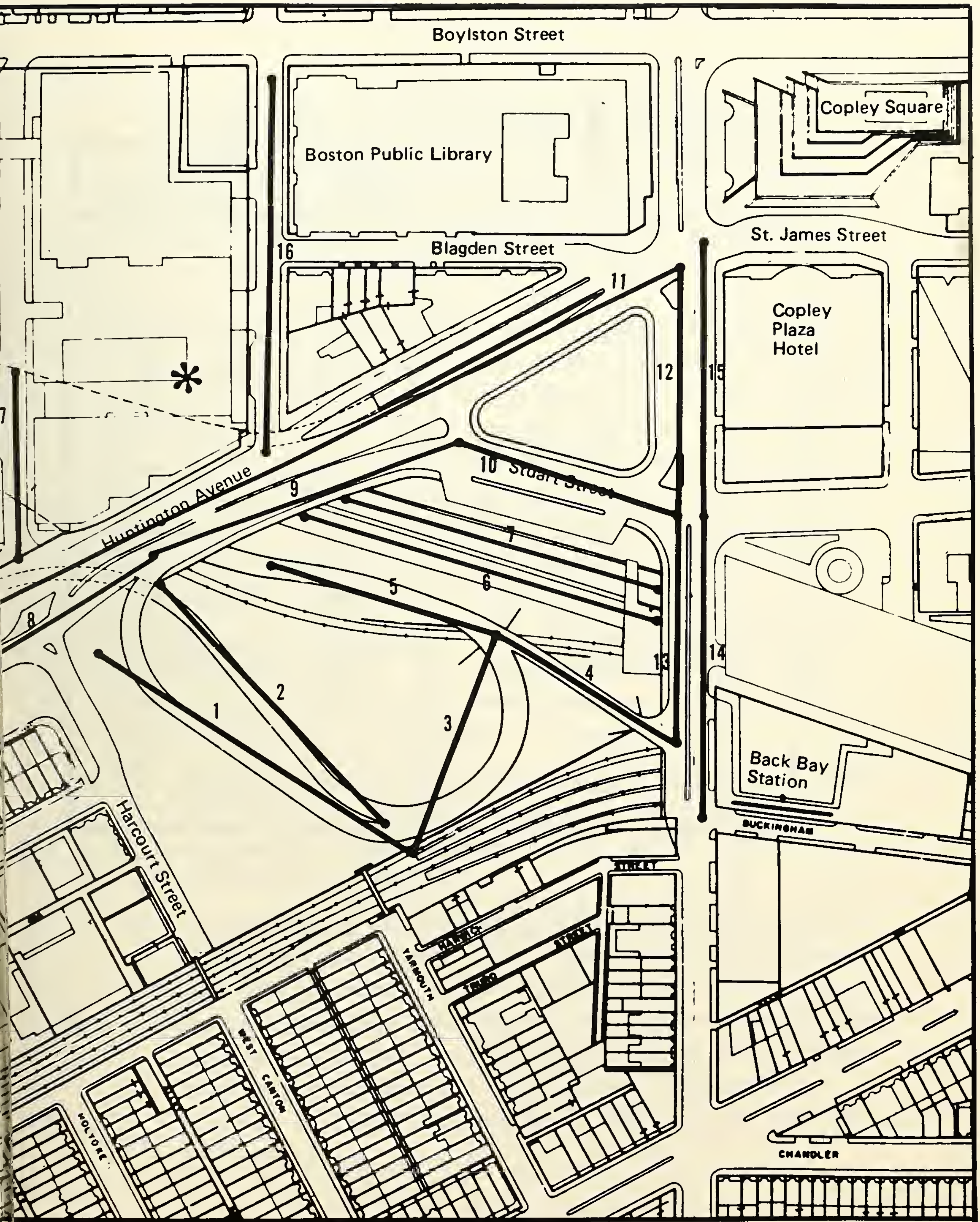


FIGURE 3.2 - EXISTING NOISE MODEL #2

TABLE 3.1

DISTANCES BETWEEN RECEPTORS AND LINKS (meters)

Link		Distance to Receptor Model #1	Distance to Receptor Model #2
1	Ramp D	59	135
2	Ramp B	75	75
3	Ramp B/D	90	169
4	Ramp C	172	216*
5	Ramp B/C/D	145	67
6	Turnpike EB	160	160*
7	Turnpike WB	183	159*
8	Huntington EB	122	66
9	Huntington EB'	129	72
10	Stuart	223	167*
11	Huntington WB	134	55
12	Dartmouth NB	229	216
13	Dartmouth SB	229	216
14	Dartmouth NB'	241	226
15	Dartmouth NB"	241	226
16	Exeter	-	30
17	Ring Rd.	-	64

*Treated as a point source.

4) Determination of Surface Character between Receptor and Link. The model allows for the increased attenuation associated with "soft surfaces" such as grass. Inspection of the study area provided this information. A soft surface was assumed for the Copley Place site.

5) Measurement of Angles to Ends of Each Link (Finite Roadway Adjustment). A perpendicular line was drawn from the receptor to the roadway, or roadway extension. Lines were then drawn from the receptor to each end of the link. Angles were measured from the perpendicular to the lines connecting the receptor to the ends of the link. Figure 3.3 shows how this was done in order to attain the correct values required for FHWA model calculations.

6) Account for Barriers. The diagram was examined for barriers between the receptor and any link. Only one existing barrier was significant. This is described in Appendix D.

7) Determination of Traffic Volumes on Each Link. Peak hour traffic volumes were provided by PBQD/NAA in the revised Copley Place Traffic report. They are presented in Table 3.2.

8) Determination of the Modal Split. The modal split between heavy trucks, light trucks, and automobiles was also provided by the traffic consultants. It was assumed that 85% of the vehicles were automobiles, 12% medium trucks, and the remaining 3% heavy trucks. This split was applied to the peak-hour traffic volumes to yield the number of vehicles per hour in each class.

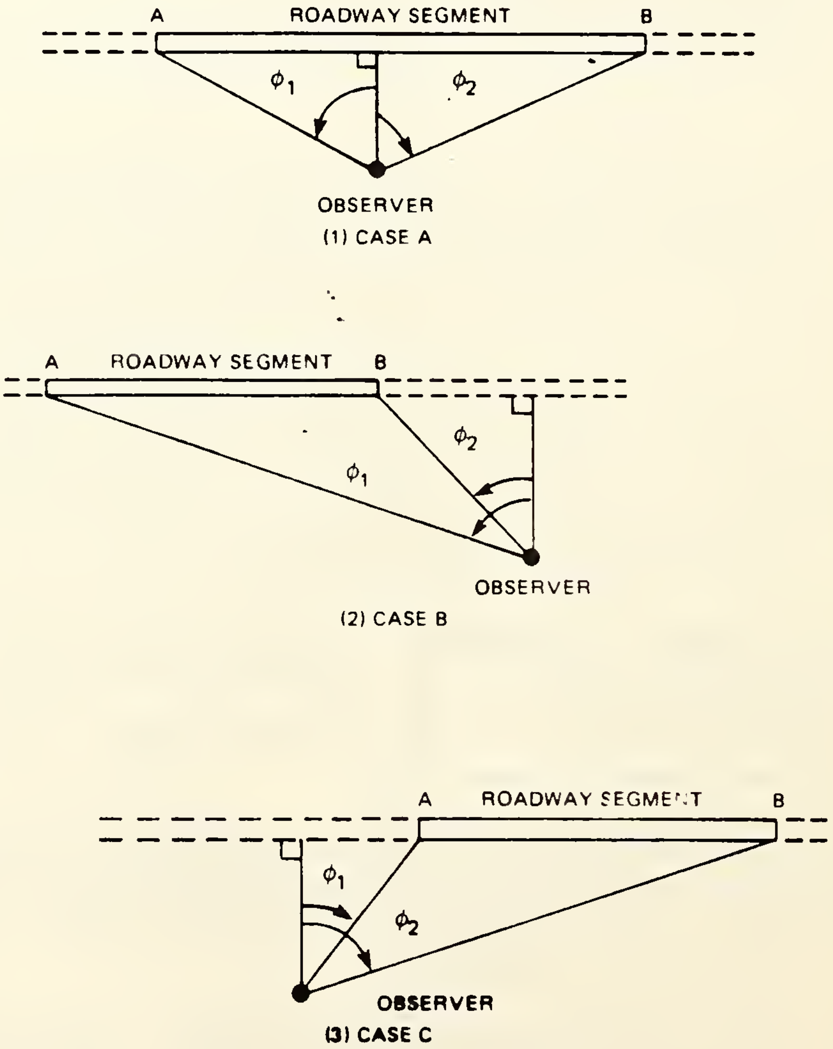


FIGURE 3.3 - ANGLE IDENTIFICATION OF ROADWAY SEGMENTS

TABLE 3.2

EXISTING TRAFFIC VOLUMES AND SPEEDS

Link		ADT	% During Peak	PHV	km/hr.
1	Ramp D	4,500	10%	450	65
2	Ramp B	3,360	10%	336	48
3	Ramp B/D	7,860	10%	786	48
4	Ramp C	2,350	10%	235	40
5	Ramp B/C/D	10,200	10%	1,020	48
6	Turnpike EB	80,000	9%	3,600	89
7	Turnpike WB			3,600	89
8	Huntington EB	26,700*	9%	1,202	8
9	Huntington EB'	8,800	9%	396	37
10	Stuart	9,500	9%	1,665	27
11	Huntington WB			1,202	8
12	Dartmouth NB	17,000**	9%	765	26
13	Dartmouth SB	12,200	9%	549	31
14	Dartmouth NB'			549	31
15	Dartmouth NB"			765	26
16	Exeter	8,000	9%	720	24
17	Ring Road			360	24

Note: A theoretical peak hour volume was calculated for the purposes of noise model calculations. It is based on the peak hour percentage of ADT. Directional split, where applicable, is assumed to be 50:50.

* 26,700 is the 2-way ADT for Huntington Avenue (links #8 and 11).

** 17,000 is the 2-lane ADT for upper Dartmouth Street (links #12 and 15).

Source: Copley Place Transportation Impacts Study PBAD/NAA, November, 1979.

9) Determination of Speed of Vehicles. This information was provided by the traffic consultants and was also presented in Table 3.2. The model does not account for speeds less than 50 km/hr. When slower speeds were encountered, 50 km/hr was used.

Once the data were collected in Steps 1 through 9, they were used to calculate the noise level contribution at each receptor from each link. The noise prediction worksheet provided in the FHWA manual facilitates this process (see Appendix D). Tables 3.3 and 3.4 show the link by link noise input for each model. The contributions from each link were added to arrive at the total traffic noise component at the receptor.

The total existing traffic noise at the Harcourt Street receptor (Model #1) is equal to 62.9 dBA. At the Gloucester Apartments, traffic noise is higher, 66.4 dBA. This is due to the higher volume of traffic adjacent to the Gloucester site. Huntington Avenue and the Massachusetts Turnpike travel lanes are closer to the Gloucester site than to Harcourt Street. These links carry large traffic volumes and account for large noise inputs into Model #2. Four links in Model #2 contribute 59 dBA each. Peak traffic contributions to Model #1 also come fro Huntington Avenue and Turnpike links. However, the resultant noise levels encountered on Harcourt Street are lower due to the greater distance from the noise source. Link #6, the Turnpike eastbound, is the peak contributor at Harcourt Street (57.7 dBA). The next largest contribution comes from Link #1, the Turnpike ramp nearest the receptor. This link accounts for a 55.4 dBA contribution.

Rail Noise

The rail noise was broken into three components for modeling purposes. The first component was the noise associated with the

TABLE 3.3

TRAFFIC NOISE EMISSION, MODEL #1

Link		$L_{eq}(PH)$
1	Ramp D	55.4
2	Ramp B	49.9
3	Ramp B/D	48.2
4	Ramp C	36.7
5	Ramp B/C/D	47.9
6	Turnpike EB	57.7
7	Turnpike WB	54.5
8	Huntington EB	53.4
9	Huntington EB'	41.0
10	Stuart	50.4
11	Huntington WB	50.6
12	Dartmouth NB	39.1
13	Dartmouth SB	38.5
14	Dartmouth NB'	39.9
15	Dartmouth NB "	38.7
	TOTAL	62.9 dBA

TABLE 3.4

TRAFFIC NOISE EMISSION, MODEL #2

Link		L_{eq}(PH)
1	Ramp D	46.5
2	Ramp B	43.4
3	Ramp B/D	43.7
4	Ramp C	39.1
5	Ramp B/C/D	52.5
6	Turnpike EB	59.0
7	Turnpike WB	59.1
8	Huntington EB	49.5
9	Huntington EB'	51.2
10	Stuart	56.5
11	Huntington WB	58.9
12	Dartmouth NB	39.4
13	Dartmouth SB	39.2
14	Dartmouth NB'	38.7
15	Dartmouth NB"	39.1
16	Exeter	59.6
17	Ring Rd.	49.7
	TOTAL	66.4 dBA

train movements on the Southwest Corridor rails (the Shore Line); the second component was rail noise associated with train movements on the B&A rail lines which parallel the Massachusetts Turnpike; the third component was the noise associated with the trains idling at Back Bay Station. The components' noise contributions were calculated individually, and logarithmically added to obtain composite rail noise contributions.

The rail noise calculations were based on a rail noise model compiled by Dr. Leonard Kurzweil, of the Transportation System Center in Cambridge, Massachusetts*.

The basic model, which is derived from field operations is as follows:

$$\left.\begin{array}{l} L_{eq}(24\text{ hour}) \\ \\ L_{dn} \\ \\ \text{CNEL} \end{array}\right\} = L_{AE(train)} + 10\ L_{eq_{10}}\ N - 49$$

where: L_{AE} is the energy sum for the train type, and

N is the number of operations of the train.

Using the Kurzweil model** total rail noise was modeled for two receptor locations. In rail Model #1, the rail noise levels at measurement site #5, on Harcourt Street were calculated. In rail Model #2, the noise levels at noise measurement site #1 at the base of the Gloucester Apartments was modeled. These are the same locations for which traffic, and other noise have been modeled. The locations of the two receptor sites and the three rail noise components are shown in Figure 3.4.

---

*Prediction of Community Noise from Rail Systems. Leonard G. Kurzweil, May 1978.

**The Kurzweil model provides for calculation of L_{eq} on a 24-hour basis. The same principles were used to calculate peak-hour L_{eq} values. The peak-hour values are a better measure of impact near a commuter rail line.

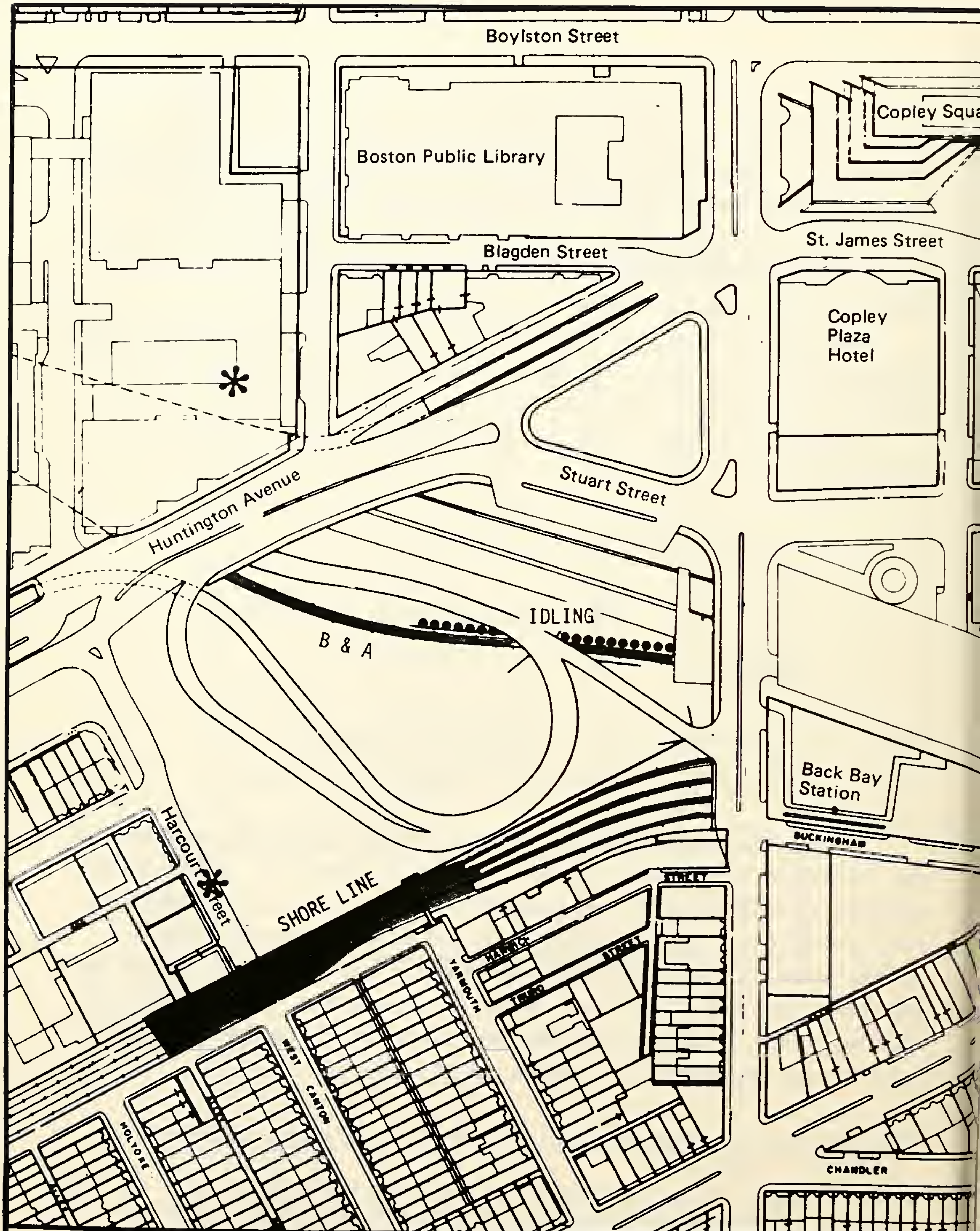


FIGURE 3.4 - LOCATIONS OF RAIL NOISE COMPONENTS

The L_{AE} values used in Model #1 are assumed, based on observations made during the noise measurement program. L_{AE} values used in the rail Model #2, for a receptor at the Gloucester Apartments measurement site, were derived using the Model #1 L_{AE} values corrected for differences in distance. The simple distance correction factor of 20 LOG D_o/D_i was used. In this factor D_o is the reference distance (i.e., the distance between the rail line source and the receptor in Model #1) and D_i is the distance from the rail line to the receptor in Model #2.

In each model case, the N values for the rail lines have been taken from rail schedules. The rail schedules were taken from the Draft EIR for Copley Place. The N values do not apply directly to the calculation for the idling components. For the idling cases, the L_{eq} values were based on estimated idling times. Each train was assumed to idle one minute, and 20% of the train trips were assumed to occur during the peak hour.

The assumptions, and the resulting noise levels used in the two noise models are outlined in Table 3.5. The calculations of these numbers are included in Appendix E. Rail noise Model #1 is probably more accurate than Model #2 due to local topography. The receptor at the base of the Gloucester Apartments is shielded from much of the rail activity by the Turnpike ramp and bridge structures. The estimated levels of Model #2 may be more accurate for the upper floors of the apartment building which have more direct line of site to the B&A tracks and Back Bay Station.

The numbers presented in Table 3.5 indicate maximum rail noise levels of 67.0 dBA at the Harcourt Street receptor and 58.8 dBA at the Gloucester Apartments. The much higher value at Harcourt Street is directly attributable to the close proximity to the Southwest Corridor rail tracks (and the Shore Line rail traffic). The peak rail noise levels at the Gloucester Apartments is a reflection of idling activity at Back Bay Station. The contribution of the rail lines themselves is relatively insignificant.

TABLE 3.5

RAIL NOISE LEVELS AND ASSUMPTIONS (dBA)

	Model #1	Model #2
B&A L_{AE}	75	*
Shore L_{AE}	84	
Idling L_{AE}	64	
B&A L_{eq} peak hour	39	38.8
Shore Line L_{eq} peak hour	66.2	52.5
Idling L_{eq} peak hour	59.1	58.7
Total peak hour L_{eq} for rail components	67.0	58.8

*Not measured for this site. Model based on L_{AE} measured at Harcourt St.

Background Noise

In order to determine the background noise at the two receptors, the traffic and rail components were added together and subtracted from the existing peak measured noise levels. The results of this calculation are presented in Table 3.6.

The background noise at Harcourt Street is calculated to be 60.1 dBA. At the Gloucester Apartment building, the background noise is equal to 64.3 dBA. This is because the Gloucester Apartment receptor is located amidst commercial activity and nearer to noise sources in Back Bay. Harcourt Street is less densely developed and less active. The monitoring location is bordered on two sides by Turnpike ramps and a railroad. Neither of these produce noise-generating activity not included in the traffic and rail models.

3.3 Existing Noise Model Results

Although the two modeled receptors have the same measured peak L_{eq} of 69 dBA, the contributions from the various components differ. This is shown in Table 3.7.

In Model #1, at the Harcourt Street receptor, rail noise is the most significant element, contributing 67.0 dBA to the peak-hour L_{eq}. Rail noise contributes only 58.8 dBA to the noise level at the Gloucester Apartments. This is because the Harcourt Street receptor is so much closer to the Shore Line activity on the Southwest corridor railway.

In Model #2, traffic and background noise are the more significant sources of noise; traffic accounting for 66.4 dBA, and background for 64.3 dBA. This is due to the proximity of Huntington Avenue and the Massachusetts Turnpike travel lanes, as well as the high level of local noise-generating commercial activity.

Harcourt Street, being more removed from these sources of noise, has lower contributions from traffic (62.9 dBA) and background noise (60.1 dBA).

TABLE 3.6

CALCULATION OF BACKGROUND NOISE

$$L_{\text{Total}} = 10 \text{ LOG } (10^{\frac{L_{\text{eq surface}}}{10}} + 10^{\frac{L_{\text{eq other}}}{10}}$$

MODEL #1

$$L_{\text{eq peak}} = 62.9_{\text{traffic}} + 59.1_{\text{idling}} + 39.0_{\text{B\&A}} + 66.2_{\text{shoreline}}$$

$$= 68.4 \text{ dBA}$$

$$69_{\text{observed}} = 10 \text{ LOG } (10^{\frac{68.4}{10}} + 10^{\frac{L_{\text{eq other}}}{10}})$$

$$L_{\text{eq other}} = 10 \text{ LOG } (10^{\frac{69}{10}} - 10^{\frac{6.84}{10}})$$

$$L_{\text{eq other}} = 60.1 \text{ dBA}$$

MODEL #2

$$L_{\text{eq peak}} = 66.4_{\text{traffic}} + 52.5_{\text{shoreline}} + 58.7_{\text{idling}} + 38.1_{\text{B\&A}}$$

$$= 67.2 \text{ dBA}$$

$$69^{*} = 10 \text{ LOG } (10^{\frac{67.2}{10}} + 10^{\frac{L_{\text{eq other}}}{10}})$$

$$L_{\text{eq other}} = 10 \text{ LOG } (10^{\frac{69}{10}} - 10^{\frac{67.2}{10}})$$

$$L_{\text{eq other}} = 64.3 \text{ dBA}$$

*Peak observed dBA at location = 66 dBA. 3 dBA added since this noise was not observed during peak hours, but at 9:55 to 10:55 AM (in 1978 study).

TABLE 3.7

NOISE MODEL SUMMARY

Model #1

$62.9_{\text{traffic}} + 67.0_{\text{rail}} + 60.1_{\text{background}} = 69\ \text{dBA}_{\text{observed}}$

Model #2

$66.4_{\text{traffic}} + 58.8_{\text{rail}} + 64.3_{\text{background}} = 69\ \text{dBA}_{\text{estimated peak}}$

4. CONSTRUCTION PHASE NOISE LEVELS

The construction period for Copley Place is expected to last approximately 3-1/2 years. During this time, the types, numbers, and locations of construction equipment will vary depending on the particular phase of construction. To investigate the potential for construction noise impacts, six time-period-equipment-location scenarios were modeled.

4.1 Inputs into Construction Noise Model

There were three main inputs for peak levels of construction noise at each of the six receptors. These are:

1) Construction equipment schedules
2) Location of construction equipment
3) Construction equipment noise emission characteristics

By examining various combinations of these inputs, worst-case construction noise scenarios were determined.

Construction Equipment Schedules

The best available construction schedule (by month) for Copley Place was provided by PBQD. The schedule breaks down construction activities into phases for each major project component. Figure 4.1 shows the construction schedule. Five major project components are depicted on this schedule:

1) Site work
2) Luxury Hotel
3) Convention Hotel
4) Infield Area
5) Housing

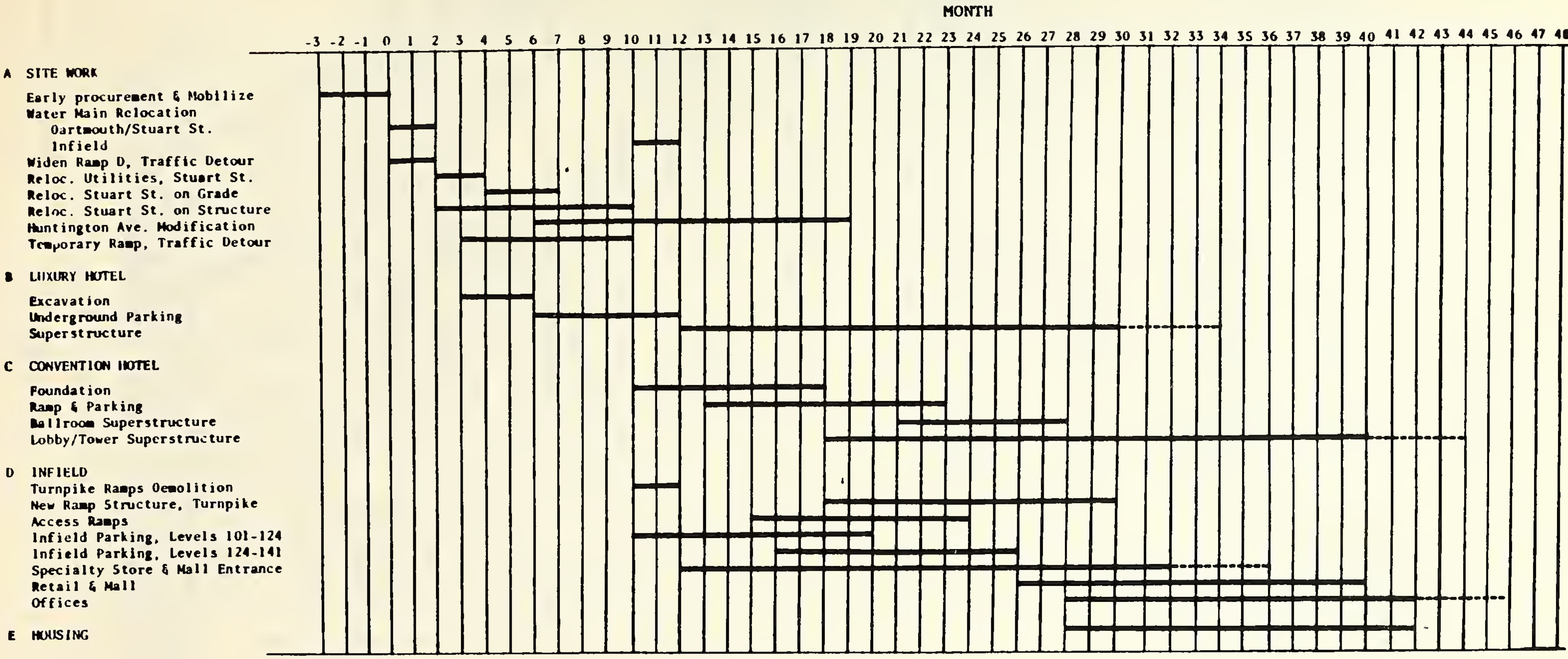


FIGURE 4.1 - PRELIMINARY CONSTRUCTION SCHEDULE

The various construction activities taking place at each component are also indicated. For each of these activities the numbers and types of proposed equipment was provided.

The numbers and types of equipment for each activity were then applied to the construction schedule.

The resulting schedule of construction equipment usage is shown in Appendix F.

Construction Equipment Location

For modeling purposes, construction equipment was assumed to be located at a theoretical site-center of activity for the project component for which it is scheduled. These site-centers are shown on Figure 4.2. All equipment scheduled for the luxury hotel, for example, is assumed to be located at B.

Construction Equipment Noise Emission Characteristics

In order to determine the noise levels associated with Copley Place construction activity, noise emissions characteristics for each type of equipment used were consulted. These are provided by the EPA and included in Document NTID 300.1*. Table 4.1 presents these construction equipment noise levels. From these levels, the approximate peak-hour L_{eq} was calculated. The L_{eq} levels are presented in Table 4.2.

For each month of construction activity modeled, constructi equipment noise emission levels were applied to the numbers and types of equipment located at the five theoretical construction activity site centers. This yielded the total construction noise emission from each location.

---

*U.S. Environmental Protection Agency; Document NTID 300.1; "Noise from Construction Equipment and Operations, Building Equipment and Home Appliances," December 1971.

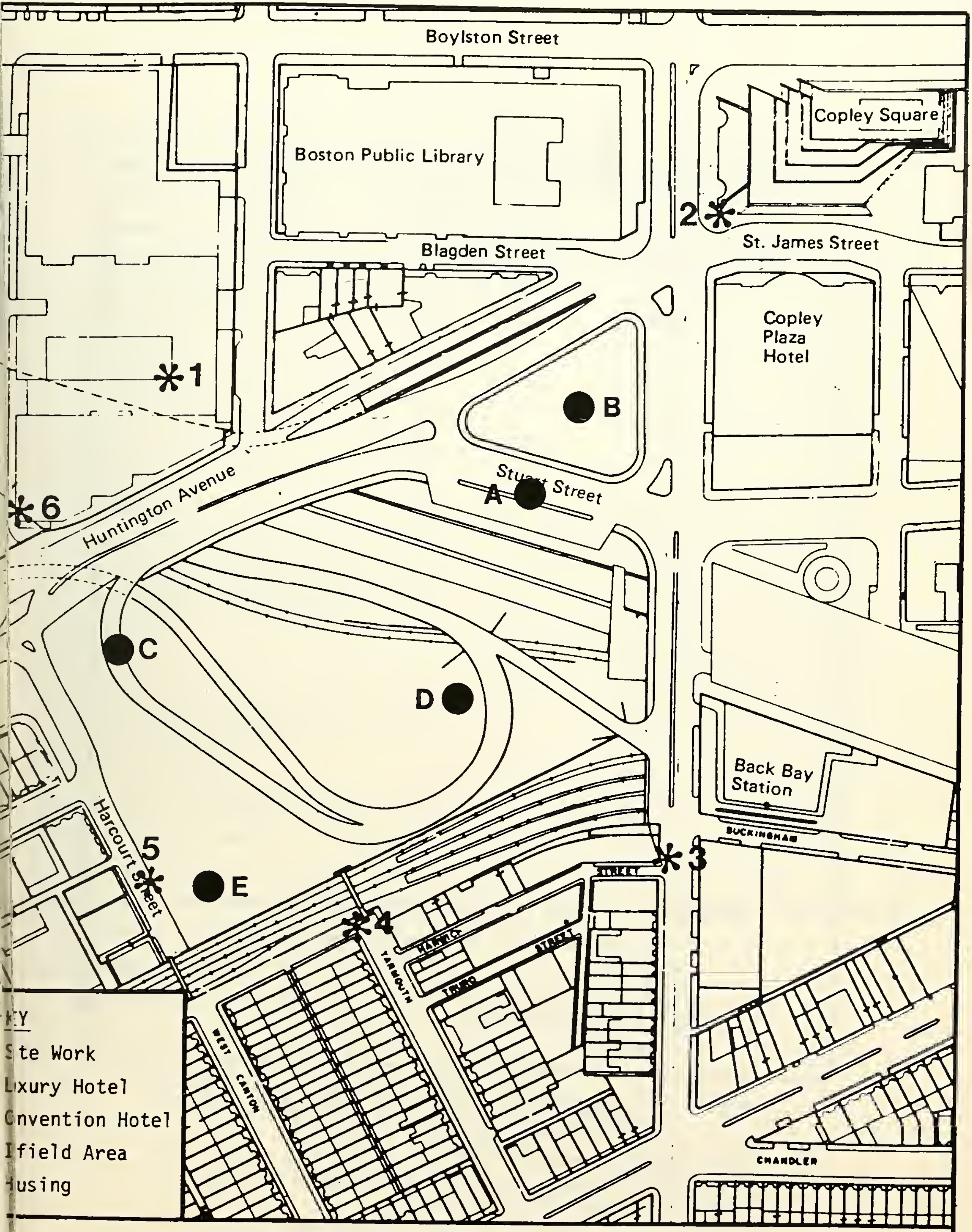


FIGURE 4.2 - THEORETICAL CONSTRUCTION ACTIVITY SITE CENTERS

TABLE 4.1

CONSTRUCTION EQUIPMENT NOISE EMISSION CHARACTERISTICS

Equipment	Noise Level (dBA)	Daily Usage Factor[**]
Earthmoving		
front loader	79	0.4
backhoes	85	0.16
dozers	80	0.4
tractors	80	0.4
scrapers	88	0.4
graders	85	0.08
truck	86[†]	0.4
paver	89	0.1
Materials Handling		
concrete mixer	85	0.4
concrete pump	82	0.4
crane	83	0.16
derrick	88	0.16
Stationary		
pumps	76	1.0
generators	78	1.0
compressors	81	1.0
Impact		
pile drivers	101	0.04
jack hammers	88	0.1
rock drills	98	0.04
penumatic tools	86	0.16
Other		
saws	78	0.04
vibrator	76	0.4
steam blowout	129	0.01
public address system	120	0.01
batch plant	93	1.0

Source: U.S. Environmental Protection Agency; Document NTID 300.1; "Noise from Construction Equipment and Operations, Building Equipment and Home Appliances," December 1971.

[*] At a reference distance of 50 feet.

[**] Defined as the time ratio of daily time at maximum engine power to the time at idle or shutdown condition.

[†] Value reflects standard, licensed for-the-road diesel trucks.

TABLE 4.2

CALCULATED APPROXIMATE PEAK L_{eq} FOR CONSTRUCTION EQUIPMENT

Equipment Type	Peak* Reference Noise Level @ 50' (dBA)	Daily* Usage Factor	Approximate[†] L_{eq} PH
Pile driver/auger	101	0.04	91 dBA
Compressor	81	1.0	81 dBA
Jackhammer	88	0.1	79 dBA
Pumps (concrete type assumed)	82	0.4	78 dBA
Backhoes	85	0.16	77 dBA
Loaders	79	0.4	75 dBA
Bulldozers	80	0.4	76 dBA
Cranes	83	0.16	75 dBA
Paving ripper (scraper)	88	0.40	84 dBA
Cherry picker (pneumatic tool)	86	0.16	78 dBA
Truck	86	0.1**	75 dBA
Paver	89	0.1	80 dBA
Roller/compactor (grader)	85	0.08	74 dBA
Concrete truck (truck)	86	0.4	82 dBA
Hoist (derrick)	88	0.16	80 dBA
Forklift (pneumatic tool)	86	0.16	78 dBA
Mortar mixer	85	0.4	81 dBA
Concrete pump	82	0.4	78 dBA

*per EPA NTID 300.1 unless otherwise noted.

**assumed value

[†] Calculated using Table 2 from Highway Noise, FHWA 1977.

4.2 Construction Noise Model

In order to determine the probable month of worst-case noise level at each site center, the construction schedule of equipment usage was studied carefully. For months with especially loud equipment or large numbers of equipment at any location, the noise emission level for that site center was calculated. Examination of the results revealed the peak noise level month at each location. Two peak months were found at the convention hotel construction activity site center (C). These months are:

Model C1/Month #3 peak of site work phase
Model C2/Month #4 peak of luxury hotel noise
Model C3/Month #13 peak of convention hotel noise
Model C4/Month #23 peak of convention hotel noise
Model C5/Month #11 peak of Office/Mall noise
Model C6/Month #28 peak of housing noise

L_{eq} noise levels for each of these months were calculated at each of the six receptors used in the noise monitoring study described in Section 2 of this report. To do this, the total noise level at each site center was corrected for the distance to each receptor. These calculations are included as Appendix G.

The results of the peak construction phase noise modeling are summarized in Table 4.3. For comparison to the Boston construction noise regulations* (see Table 4.4), the six models were re-run without impact devices, such as paving rippers and pile drivers. The results of the second model run are also outlined in Table 4.3.

---

*The Boston regulation applies to L_{10} levels, rather than L_{eq}. The L_{10} levels will probably be 1 or 2 dB higher than L_{eq} numbers. Noise from impact devices is not regulated by the ordinance.

TABLE 4.3

SUMMARY OF CONSTRUCTION PHASE NOISE LEVELS

Site # and Location	Peak Construction Phase Noise Level (L_{eq})	Peak Noise Without Impact Equipment (L_{eq})	Applicable City Noise Standard*	Existing Peak Noise Levels (L_{eq})
Receptor 1 - Gloucester Apartments	77.9	75.6	75	69
Receptor 2 - Copley Square	77.1	70.7	80	67
Receptor 3 - Dartmouth Street	80.4	74.5	80	72
Receptor 4 - Tent City	80.7	75.6	75/80	70
Receptor 5 - Harcourt Street	85.5	77.9	75/80	69
Receptor 6 - Mini-Pru	81.4	78.2	80	66

*L_{10} Without impact equipment. For comparison with L_{eq} noise levels, subtract 1-2 dB.

TABLE 4.4

CITY OF BOSTON
SUMMARY OF RESTRICTION ON
CONSTRUCTION SITE NOISE*

3.1 MAXIMUM LEVELS

Land Use of Affected Property	Maximum Noise Level Value Measure at Lot Line of Affected Property (dBA)	
	L_{10}	Maximum Noise Level
Residential or Institutional	75	86
Business or Recreational	80	--
Industrial	85	--

(To be evaluated at distances not closer ~~greater~~ than 50 feet from nearest ~~any~~ active construction device, using slow response of sound level meter.

3.2 MEASUREMENTS

- A-weighted
- At 10-second intervals, 100 sample total
- Measured L_{10} must exceed background L_{10} by 5 dBA for violation of ~~4~~3.1

3.4 Maximum levels under ~~4~~3.1 do not apply to impace devices (pile drivers, paving breakers, riveters, etc.)

---

*City of Boston Air Pollution Control Commission, "Regulations for the Control of Noise in the City of Boston." Regulation 3, effective January 1, 1976.

4.3 Construction Noise Model Results

Receptor 1, Gloucester Apartments

Peak construction noise levels (L_{eq}) will probably exceed 77 dBA during pile driving activities. When impact devices are not used, maximum L_{eq} noise levels will be about 75-76 dBA. These are increases of 6-9 dB above the existing peak noise levels at the site. The predicted noise levels exceed the 75 dBA (Leq; about 73-74 dBA L_{eq}) construction site noise level specified by Regulation 3. The increased noise levels may be perceived as aggravating to residents of the apartment tower.

Receptor 2, Copley Square

Peak construction noise levels (L_{eq}) will be approximately 77 dB. Peak levels without impact devices will be about 71 dB. These are increases of 4-10 dB above the existing estimated peak L_{eq} levels at Copley Square. The peak predicted levels fall well within the maximum levels specified by the city construction noise regulation level (80 dBA L_{10}, 78-79 dBA L_{eq}).

Receptor 3, Dartmouth Street

Peak equivalent construction noise levels will be just over 80 dBA, including pile drivers and other impact equipment devices. Without impact equipment, the peak predicted construction noise level is 74.5 dB. These are increases of about 3-8 dB over existing noise levels. The relatively small increase, which is within the city's specified L_{10} ceiling of 80 dB, is due to the proximity of that receptor location to the rail activity at Back Bay Station.

Receptor 4, Tent City

Estimated peak construction noise levels (L_{eq}) will be just under 81 dB with the pile driving activity and 75-76 dB without impact devices. This is an increase of about 5-10 dB above the existing noise levels at the site and slightly exceeds or is within the L_{10} limit of 75/80 dB set by the city construction noise regulation.

Receptor 5, Harcourt Street

The 85 dB equivalent noise level predicted for Harcourt Street is the maximum predicted level associated with the Copley Place construction. Even without the pile driving for the housing component which causes this peak noise, levels may be as high as 78 dB. This increase of 9 dB exceeds the 75 dB (L_{10}; 73-74 dBA L_{eq}) construction noise limit specified for housing.

The peak levels may be attributed to the proximity of this particular site to construction activities. The site is immediately opposite the proposed housing construction activities, and relatively close to the office, mall, and convention hotel construction as well.

Receptor 6, Mini-Pru

Peak L_{eq} construction noise at the base of the Mini-Pru may exceed 81 dB during pile driving for the nearby convention hotel. Peak noise levels for non-impact construction equipment will be about 78 dB, which is about equal to the city's regulate L_{10} level of 80 dB for business properties, or 78-79 dBA (L_{eq}).

Southwest Corridor Project Construction

It is anticipated that construction work on the Southwest Corridor Project will be occuring simultaneously with construction work on the Copley Place Project. The Southwest Corridor Project will produce construction noise levels which will affect people in residential areas on the southern border of the Copley place site (i.e., along Harcourt, Yarmouth, Carleton, etc. Streets)*. Both construction projects involve various quantities and types of construction equipment. Thus, during the construction of these projects, three types of noise level conditions may exist at the aforementioned noise sensitive receptor area. Construction noise levels will be predominantly due to (1) the Southwest Corridor construction activities; (2) the Copley Place construction activities; or (3) approximately equal contributions from both projects. The maximum "additive effect" would occur when equal noise level contributions from both projects exist at the same time, in which case, the resulting noise level would be 3 dBA more than the contribution from either project. A 3 dBA change in noise level is just barely over the threshold of human perception and is not considered significant by most people; however, it may cause additional exceedance.

The predicted construction noise levels are on the conservative side. Barrier effects which will occur during latter stages of construction, when the super-structure is already erected, are not considered.

In order to mitigate the impacts of these noise levels, construction activities will not occur before 8:00 AM or after 6:00 PM. Whever feasible, mufflers and other noise abatement measures will be used to minimize noise levels.

---

*Volume one Final EIS Orange Ling Relocation and Arterial Street Location, Page 5-55.

5. OPERATIONAL NOISE LEVELS (1983)

5.1 Causes of Future Noise Impacts

Development of the Copley Place Project involves the potential for both improving and degrading the noise environment in the vicinity of the project site. The factors that involve potential for increasing noise levels may be broken into two major components:

1) Introducing additional "mobile source" traffic activity in the street system around the project site; and
2) Introducing new "point source" mechanical equipment to the site area. The heating, ventilating and air conditioning equipment (HVAC) includes ventilation fans and cooling towers which may be considered new sources of noise in the area.

On the other hand, the design of the project, together with the design of the adjacent Orange Line improvement, incorporates changes which may significantly reduce noise generation in the area. These design changes include:

1) Decking over the rail lines which effectively removes rail noise as a major source in the area;
2) Decking over the Turnpike section through the site, which removes the largest single traffic carrying link in the system as a noise source;
3) Decking over the large majority of the Turnpike ramps thereby reducing the contribution of these elements to local noise levels; and

4) Introducing new structures on the site which provide additional acoustical barriers in place of the relatively open site which exists now. The South End, for instance, becomes buffered from Huntington Avenue traffic noise.

The net effect of these positive and negative changes to ambient noise levels is a function of receptor location relative to the project site and the surrounding street network. Receptors around the site fall into two categories with respect to potential changes in noise levels. The first category consists of those receptors located adjacent to the major traffic arterials which will not be decked in the future. These arterials include Huntington Avenue and Dartmouth Street. These receptors are represented by noise monitoring stations 1, 2, and 6 as described in Section 3.1 of this report and include the Gloucester Apartments, hotels, and various office and commercial facilities abutting the site. At these locations, the project will cause some increases in traffic volumes, above those projected for area-wide growth. These traffic increases will contribute to local noise levels. At the same time, these locations will receive some attenuation due to the decking of the more distant rail lines and street segments. These two phenomena tend to balance, leaving relatively little total change.

The second category consists of those receptors located adjacent to the major traffic arteries and rail lines that will be decked in the future. These receptors are represented by noise monitoring stations 3, 4, and 5 and include the residential units on Harcourt Street, the Tent City site, and the Dartmouth Street site. For these sites, the predominant source of noise will be eliminated and more significant reductions in noise levels may take place.

5.2 Future Noise Level Models

In order to quantify the potential changes in noise levels on completion of Copley Place, the two existing noise level models were run for the future case. In order to predict future noise levels, changes in traffic, changes in rail activity, the effects of decks and barriers, and the addition of HVAC mechanical systems for the preferred alternative were incorporated in each model.*

Traffic and Rail

In order to estimate future noise levels, each traffic and rail link was examined for changes in geometry. If the link will be completely shielded, a 25 dBA reduction to the existing level is assumed. This is considered conservative since the noise from decked links may well be fully eliminated. Links which remain significantly exposed to the receptor are re-run using 1983 traffic figures.**

Link 18, Harcourt Street, was re-run assuming a new modal split of 50% automobiles, and 25% each of heavy and medium trucks. This is to account for the new Copley Place service entrance located on that link.

The treatment of each traffic link in the two future noise models is shown in Tables 5.1 and 5.2. Worksheets for links re-run with future traffic volumes are in Appendix H. Since all the rail noise links will be fully decked, a 25 dBA reduction was assumed for the total rail component from the existing noise level models.

---

*Noise levels associated with the alternative program would not be appreciably different since all roadway and rail barriers and traffic predictions remain constant.

**Supplied by traffic consultants.

TABLE 5.1

TRAFFIC NOISE EMISSIONS, FUTURE CASE MODEL #1

Link		Existing L_{eq}	-25 dBA*	Future L_{eq}
1	Ramp D	55.4	-25	30.4
2	Ramp B	49.9	-25	24.9
3	Ramp B/D	48.2	-25	23.2
4	Ramp C			0
5	Ramp B/C/D	47.9	-25	22.9
6	Turnpike EB	57.7	-25	32.7
7	Turnpike WB	54.5	-25	29.5
8	Huntington EB			45.4
9	Huntington EB'	41.1	-25	16.0
10	Stuart	50.4	-25	25.4
11	Huntington WB			44.8
12	Dartmouth NB	39.1	-25	14.1
13	Dartmouth NB	38.5	-25	13.5
14	Dartmouth SB'	39.9	-25	14.5
15	Dartmouth SB''	38.7	-25	13.7
18	Harcourt Street (service entrance)			55.4
	TOTAL			56.2 dBA

*-25 dBA attenuation factor assumed for completely shielded links.

TABLE 5.2

TRAFFIC NOISE EMISSIONS, FUTURE CASE MODEL #2

Link		Existing L_{eq}	-25 dBA*	Future L_{eq}
1	Ramp D			44.0
2	Ramp B	43.4	-25	18.4
3	Ramp B/D	43.7	-25	18.7
4	Ramp C	0		0
5	Ramp B/C/D	52.5	-25	27.5
6	Turnpike EB	59.0	-25	34.5
7	Turnpike WB	59.1	-25	34.6
8	Huntington EB			50.2
9	Huntington EB'			56.7
10	Stuart			51.8
11	Huntington WB			59.6
12	Dartmouth NB	39.4	-25	14.4
13	Dartmouth NB	39.2	-25	14.2
14	Dartmouth SB'	38.7	-25	13.7
15	Dartmouth SB"	39.1	-25	14.1
16	Exeter			61.3
17	Ring Rd.			50.0
18	Harcourt Street (service entrance)			45.1
	TOTAL			65.0 dBA

*-25 dBA attenuation factor assumed for completely shielded links

Background

Background noise levels are assumed to remain the same.

HVAC

Added to the traffic, rail, and background levels is the noise contribution from the Copley Place HVAC equipment. The locations and numbers of fans were provided by the architect.* Figure 5.1 shows these locations. Each fan is assumed to be 54 dBA at 100 feet.** From this information, distance attenuation corrections were calculated and barrier adjustments assumed. This information is presented in Appendix I along with the heights of the vents. This model was run for all six of the noise receptor locations. The results are presented in Table 5.3.

5.3 Future Noise Model Results

After each component to future noise was calculated, they were added together to find the total of predicted future noise. Table 5.4 presents a summary of the future noise calculations.

The calculations indicate a reduction of about 1 dB for the future case at the Gloucester Apartments site. This change is probably below the threshold at which it would be noticed.

The future estimated peak noise level at Harcourt Street will decrease by 5-6 dBA even though there will be a significant increase in noise levels associated with the service entrance located on the street. A 5-6 dBA decrease is large enough to be perceived by residents as an improvement, but annoyance associated with service vehicles may offset this perception.

---

*The Architects Collaborative, Cambridge, Massachusetts. Howard Elkus, head project architect.

**Copley Place Draft Environmental Impact Report, 1978.

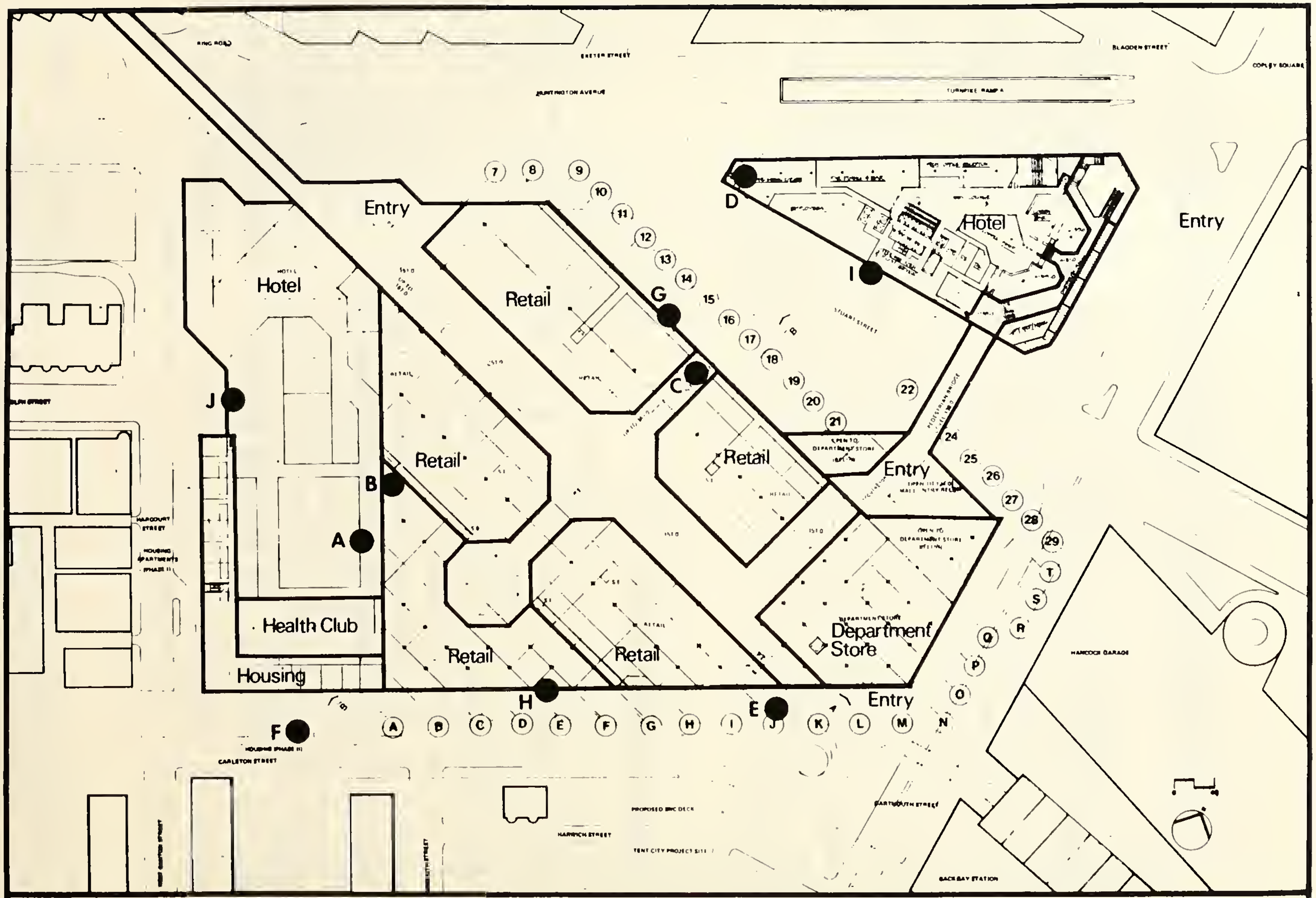


FIGURE 5.1 - SCHEMATIC LOCATION OF HVAC EQUIPMENT

TABLE 5.3

VENT NOISE COMPONENT

Vents	Receptors 1	2	3	4	5	6
A	36	26	37	50	51	37
B	32	27	36	48	49	38
C	51.4	42.4	44.4	40.4	39.4	43.4
D	-	-	-	-	-	-
E	29	28	52	35	36	28
F	33	25	42	56	50	30
G	49.8	33.8	40.8	36.8	36.8	41.8
H	29	27	46	53	40	29
I	39	32	36	30	29	40
J	-	-	-	-	-	-
Total Vent Noise at each Receptor	54.0	43.7	55.0	58.9	55.2	47.8

TABLE 5.4

PREDICTED NOISE LEVELS (L_{eq})

Receptor #1 Gloucester Apts.	Existing 1979 Condition	Future* 1983 Condition
Peak Traffic	66.4	65.0
Peak Rail	58.8	33.8
Peak Copley HVAC	-	54.0
Peak Background	64.3	64.3
Peak Total	69.0	67.9 dB
Receptor #4 Harcourt Street		
Peak Traffic	62.9	56.2
Peak Rail	66.9	41.9
Peak Copley HVAC	-	58.9**
Peak Background	60.1	60.1
Peak Total	69.0	63.5 dB

*A 25 dB reduction in noise is assumed for transportation links which will be decked over.

It is likely that receptor #6, the Mini-Pru, and receptor #2, at Copley Square, will be affected in a manner similar to receptor #1 at the Gloucester apartment building. There will be a minimal reduction in future noise levels, and this will be perceived as "no change" from existing conditions. Receptors #3 and #4 at Dartmouth Street and Tent City, respectively, will likely have reduced noise levels similar to those at Harcourt Street. These reductions of approximately 4-6 dB will be perceived as noticeable reductions.

The calculated reduction in future noise peak levels (5-6 dB) at Harcourt Street also implies that future L_{dn} levels will be below the existing level of 66.7 dB. L_{dn} will probably not decrease by 5-6 dB, a 3-4 dB reduction is more likely since evening levels will not decrease as significantly as day time peak noise. A 3 dB reduction, however, results in an L_{dn} of 63.7 dB below the HUD threshold of 65 dB for "acceptable" sites for housing.

5.4 Significance of Noise Impacts

Noise impacts are most often judged according to two sets of criteria. The first set of criteria are the applicable government standards and regulations. The federal, state, and local controls often specify noise level ceilings for both the operational and construction phases of new projects. The second set of criteria which have already been discussed are impacts judged according to relative changes associated with a new facility. Increases of 5 to 10 dB may be perceived to be a moderate impact, and increases of 10 dB or more are usually considered significant, even where no standards apply.

The federal regulations that apply to Copley Place are the new HUD standards for new housing at L_{dn} = 65, which are outlined in Section 2.3 and included in Appendix C. No other federal regulations apply directly to the community noise resulting from the project. As mentioned, future L_{dn} is estimated to be between 63 and 64 dBA, below the HUD threshold of 65 dBA for L_{dn}.

Massachusetts has noise regulations that require appropriate steps be taken to prevent or suppress the generation of "...industrial and commercial sources of sound, and other man-made sounds that cause noise." Specific guidelines issued by the State Department of Environmental Quality Engineering for the approval of a facility are that the following conditions be avoided:

1) increasing the broadband noise level in excess of 10 dB(A) above background; or

2) producing a pure tone condition.

The broadband background noise level referred to is interpreted as the background or L_{90} level. A pure tone condition is considered to exist when the sound level of an octave band exceeds the average sound level of adjacent octave bands by 3 dB or more.

Copley Place will not increase the broadband background noise by 10 dBA above background noise. The (L_{eq}) noise levels modeled at the receptors studied decreased by 2% and 8%. It is no anticipated that Copley Place will produce any pure tone conditions. The only noise source to be introduced by Copley Place is the HVAC equipment. This equipment is standard and will have no impacts other than adding to the background noise.

Boston's noise regulations apply to both construction and operational phases of the project. Regulation 3, covering construction noise, was summarized in Table 4.4. For stationary, steady sources of noise, characteristic of the operational phase of the project, Regulation 2 applies. This latter regulation stipulates maximum noise levels (on an octave band basis) that must not be exceeded on abutting property lines.

The stipulated noise levels are function of the zoned land use and time of day (approximately corresponding to a distinction between the normal hours of commerce - 7:00 AM to 6:00 PM daily except Sunday - and other times). This regulation is presented in Table 5.5.

Receptors #4 and #5 used in this study are located in districts zoned for residential use. The others are in business zones. However, all the actual land uses are typical of those in mixed-use areas. Immediately adjacent to the monitoring sites, activities include commercial, office, transportation, and institutional activities.

Measured and predicted noise levels are also more typical of an area of combined residential and industrial usage. Existing L_{eq} noise levels equal 69 dBA. This value is above the City of Boston noise standards presented in Table 5.5. For residential/industrial zones, the limit is 65 dBA, for residential zones it is 60 dBA.

At the Gloucester Apartments, a small noise level decrease is expected. Future noise levels are predicted to be 67.9 dBA; a 1.1 dBA decrease from existing levels. This is still above the 60 dBA residential and the 65 dBA residential/industrial noise limits.

At Harcourt Street, the future noise level, 63.5 dBA, will still be above the residential zone limit of 60 dBA. However, the 5.5 predicted future noise level decrease associated with Copley Place will cause noise levels at this location to fall below the 65 dBA threshold for residential/industrial zones.

TABLE 5.5

CITY OF BOSTON
TABLE OF ZONING DISTRICT NOISE STANDARDS
MAXIMUM ALLOWABLE SOUND PRESSURE LEVELS

Octave Band Center Frequency of Measurement (Hz)	Residential		Residential-Industrial		Industry	Business
	Daytime	All Other Times	Daytime	All Other Times	Anytime	Anytime
31.5	76	68	79	72	83	79
63	75	67	78	71	82	78
125	69	61	73	65	77	73
250	62	52	68	57	73	68
500	56	46	62	51	67	62
1000	50	40	56	45	61	56
2000	45	33	51	39	57	51
4000	40	28	47	34	53	47
8000	38	26	44	32	50	44
Approximate Single-Number-System [dB(A)]**	60	50	65	55	70	65

Notes: 1) Noise standards are extracted from Regulation 2.5, City of Boston Air Pollution Control Commission, "Regulations for the Control of Noise in the City of Boston" effective January 1, 1976.

2) Reference pressure of 2×10^{-5} N/m^2.

*Daytime includes the period between 7:00 A.M. and 6:00 P.M. daily except Sunday

**For preliminary survey and monitoring only.

APPENDIX

APPENDIX A BACKGROUND NOISE INFORMATION
APPENDIX B DESCRIPTION OF 24-HOUR NOISE MONITORING PROCEDURE
APPENDIX C HUD REGULATIONS
APPENDIX D TRAFFIC MODEL
  1. Copy of FHWA Model
  2. Worksheets
APPENDIX E RAIL NOISE CALCULATIONS
APPENDIX F CONSTRUCTION EQUIPMENT SCHEDULE
APPENDIX G CONSTRUCTION NOISE CALCULATIONS FOR EACH RECEPTOR
APPENDIX H FUTURE-CASE TRAFFIC MODELS
APPENDIX I HVAC EQUIPMENT MODEL

APPENDIX A

BACKGROUND NOISE INFORMATION

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

RT NO. 550/9-79-100	2	3. RECIPIENT'S ACCESSION NO.
AND SUBTITLE tective Noise Levels lensed Version of EPA Levels Document		5. REPORT DATE November 1978 6. PERFORMING ORGANIZATION CODE ONAC
OR(S) Office of Scientific Assistant to DAA/Noise		8. PERFORMING ORGANIZATION REPORT NO.
RMING ORGANIZATION NAME AND ADDRESS ONAC		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
SORING AGENCY NAME AND ADDRESS ironmental Protection Agency ice of Noise Abatement & Control (ANR-471) M Street, S.W. ington, D.C. 20460		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/ONAC
PLEMENTARY NOTES		

TRACT

s publication is intended to promote understanding of EPA's findings about els of environmental noise that protect public health and welfare. It seeks clarify the proper use of the 1974 "Levels Document" by interpreting its tents in less technical terms. The manual deals with measurement descriptors f environmental noise. Also addressed are the best understood effects of noise people (hearing damage, speech interference and annoyance). Protective levels summarized.

KEY WORDS AND DOCUMENT ANALYSIS

DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
ironmental noise levels, indoor and door levels, measurement descriptors, se exposure patterns, hearing damage, ech interference, annoyance, pro-tive noise exposures		

TRIBUTION STATEMENT ited supply available at EPA/ONAC or S, Springfield, VA 22151	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 25
	20. SECURITY CLASS *(This page)*	22. PRICE

rm 2220-1 (9-73)

ABOUT SOUND

The sound we hear is the result of a sound source inducing vibration in the air. The vibration produces alternating band of relatively dense and sparse particles of air, spreading outward from the source in the same way as ripples do on water after a stone is thrown into it. The result of the movement of the particles is a fluctuation in the normal atmospheric pressure, or sound waves. These waves radiate in all directions from the source and may be reflected and scattered or, like other wave actions, may turn corners. When the source stops vibrating, the sound waves disappear almost instantaneously, and the sound ceases. The ear is extremely sensitive to sound pressure fluctuations, which are converted into auditory sensations.

Sound may be described in terms of three variables:

1. Amplitude (perceived as loudness)
2. Frequency (perceived as pitch)
3. Time pattern

Amplitude

Sound pressure is the amplitude or measure of the difference between atmospheric pressure (with no sound present) and the total pressure (with sound present). Although there are other measures of sound amplitude, sound pressure is the fundamental measure and is the basic ingredient of the various measurement descriptors in the next section, "Measurement of Environmental Noise."

The unit of sound pressure is the decibel (dB); thus it is said that a sound pressure level is a certain number of decibels. The decibel scale is a logarithmic scale, not a linear one such as the scale of length. A logarithmic scale is used because the range of sound intensities is so great that it is convenient to compress the scale to encompass all the sounds that need to be measured. The human ear has an extremely wide range of response to sound amplitude. Sharply painful sound is 10 million times greater in sound pressure than the least audible sound. In decibels, this 10 million to 1 ratio is simplified logarithmically to 140 dB.

Another unusual property of the decibel scale is that the sound pressure levels of two separate sounds are not directly (that is, arithmetically) additive. For example, if a sound of 70 dB is added to another sound of 70 dB, the total is only a 3-decibel increase (to 73 dB), not a doubling to 140 dB. Furthermore, if two sounds are of different levels, the lower level adds less to the higher as this difference increases. If the difference is as much as 10 dB, the lower level adds almost nothing to the higher level. In other words, adding a 60 decibel sound to a 70 decibel sound only increases the total sound pressure level less than one-half decibel.

Frequency

The rate at which a sound source vibrates, or makes the air vibrate, determines frequency. The unit of time is usually one second and the term "Hertz" (after an early investigator of the physics of sound) is used to designate the number of cycles per second.

The human ear and that of most animals has a wide range of response. Humans can identify sounds with frequencies from about 16 Hz (Hertz) to 20,000 Hz. Because pure tones are relatively rare in real-life situations, most sounds consist instead of a complex mixture of many frequencies.

Time Pattern

The temporal nature of sound may be described in terms of its pattern of time and level: continuity, fluctuation, impulsiveness, intermittency. Continuous sounds are those produced for relatively long periods at a constant level, such as the noise of a waterfall. Intermittent sounds are those which are produced for short periods, such as the ringing of a telephone or aircraft take-offs and landings. Impulse noises are sounds which are produced in an extremely short span of time, such as a pistol shot or a hand clap. Fluctuating sounds vary in level over time, such as the loudness of traffic sounds at a busy intersection.

MEASUREMENT OF ENVIRONMENTAL NOISE: SOUND DESCRIPTORS

EPA has adopted a system of four "sound descriptors" to summarize how people hear sound and to determine the impact of environmental noise on public health and welfare. These four descriptors are: the A-weighted Sound Level, A-weighted Sound Exposure Level, Equivalent Sound Level, and Day-Night

Sound Level. They are related but each is most useful for a particular type of measurement. The descriptors and some examples of their uses are described below.

A-weighted Sound Level

One's ability to hear a sound depends greatly on the frequency composition of the sound. People hear sounds most readily when the predominant sound energy occurs at frequencies between 1000 and 6000 Hertz (cycles per second). Sounds at frequencies above 10,000 Hertz (such as high-pitched hissing) are much more difficult to hear, as are sounds at frequencies below about 100 Hz (such as a low rumble). To measure sound on a scale that approximates the way it is heard by people, more weight must be given to the frequencies that people hear more easily.

A method for weighting the frequency spectrum to mimic the human ear has been sought for years. Many different scales of sound measurement, including A-weighted sound level (and also B, C, D, and E-weighted sound levels) have evolved in this search. A-weighting was recommended by EPA to describe environmental noise because it is convenient to use, accurate for most purposes, and is used extensively throughout the world. Figure 1 shows the A-weighted levels of some environmental noises. Note that these ranges of measured values are the maximum sound levels.

The A-weighting of frequency also is used in the three descriptors discussed below. When used by itself, an A-weighted decibel value denotes either a sound level at a given instant, a maximum level, or a steady-state level. The following three descriptors are used to summarize those levels which vary over time.

Sound Exposure Level - Exceedance Levels

Since the levels of many sounds change from moment to moment, this variation must also be accounted for when measuring environmental noise. One method for measuring the changing magnitude of sound levels is to trace a line on a sheet of moving paper, so that the movement of the pen is proportional to the sound level in decibels. Figure 2 illustrates such a recording, about which several features are noteworthy. First, the sound level varies with time over a range of about 30 dB. Second, the sound appears to be characterized by a fairly steady-state lower level, upon which are superimposed sound levels associated with individual events. This fairly constant lower level is often called the background ambient sound level.

Each single event in Figure 2 may be partially characterized by its maximum level. It may also be partially characterized by its time pattern. In the example, the sound level of the aircraft is above that of the background ambient level for about a minute, whereas the sound levels from cars are above the background level for much less time.

The duration of sounds with levels that vary from moment to moment is more difficult to characterize. One way is to combine the maximum sound level with the length of time during which the sound level is greater than a certain number of decibels below the maximum level — for example, the number of seconds that the sound rises from 10 dB below maximum, as in Figure 3.

Using this procedure one can measure the total energy of the sound by summing the intensity during the exposure duration. This procedure produces the second measurement descriptor, *sound exposure level* (L_S), referred to in the Levels Document as the single event noise exposure level (SENEL).

Equivalent Sound Level

Yet another method of quantifying the noise environment is to determine the value of a steady-state sound which has the same A-weighted sound energy as that contained in the time-varying sound. This is the third measurement descriptor, termed the *Equivalent Sound Level* (L_{eq}). The Equivalent Sound Level is a single value of sound level for any desired duration, which includes *all* of the time-varying sound energy in the measurement period. In Figure 2, for example, the L_{eq} equals about 58 dB, indicating that the amount of sound energy in all the peaks and valleys in the figure is equivalent to the energy in a continuous sound of 58 dB.

The major virtue of the Equivalent Sound Level is that it correlates reasonably well with the effects of noise on people, even for wide variations in environmental sound levels and time patterns. It is used when only the durations and levels of sound, and not their times of occurrence (day or night), are relevant. It is easily measurable by available equipment. It also is the basis of a fourth and final measurement descriptor of the total outdoor noise environment, the *Day-Night Sound Level* (L_{dn}).

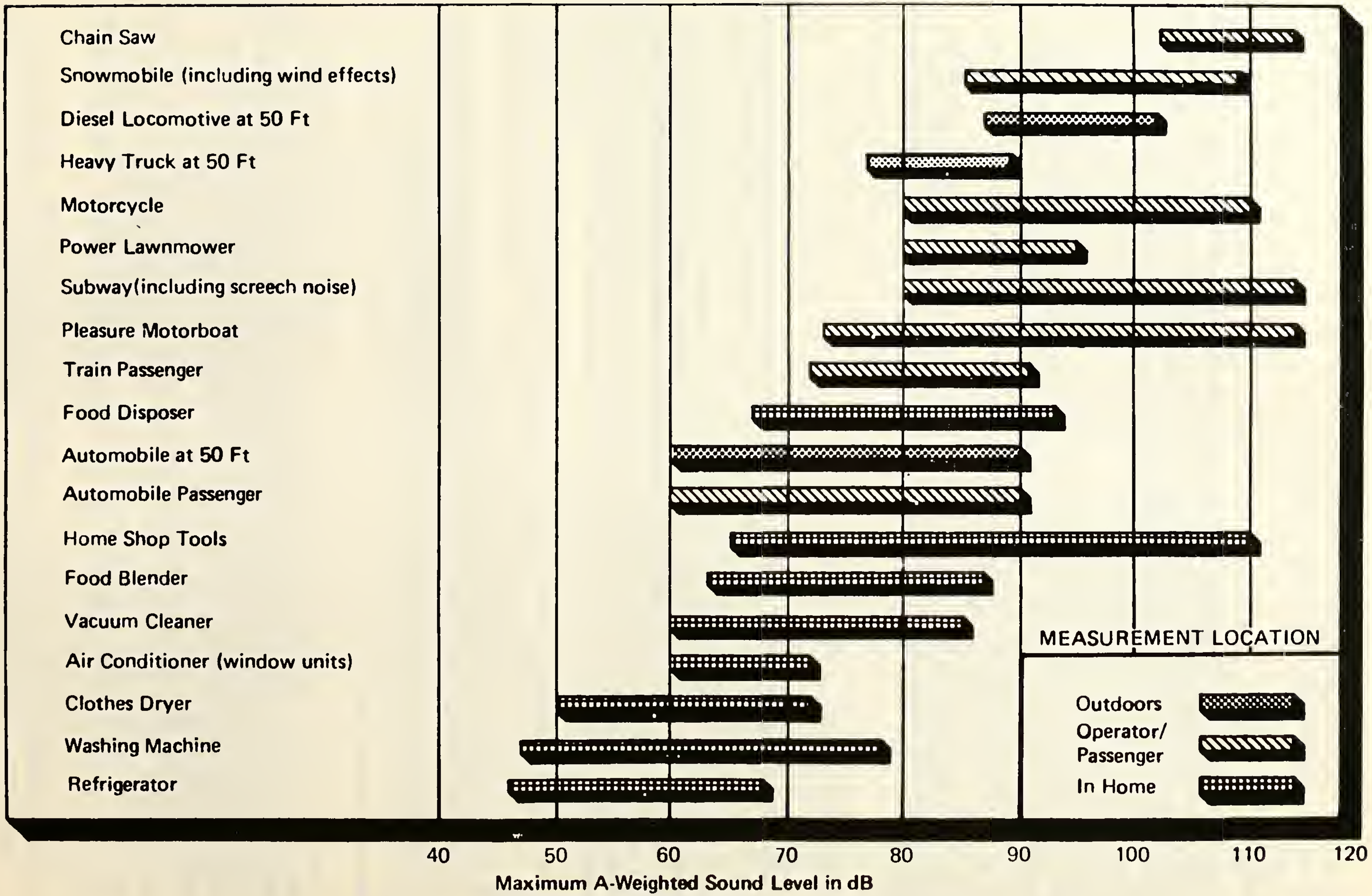


FIGURE 1. TYPICAL RANGE OF COMMON SOUNDS

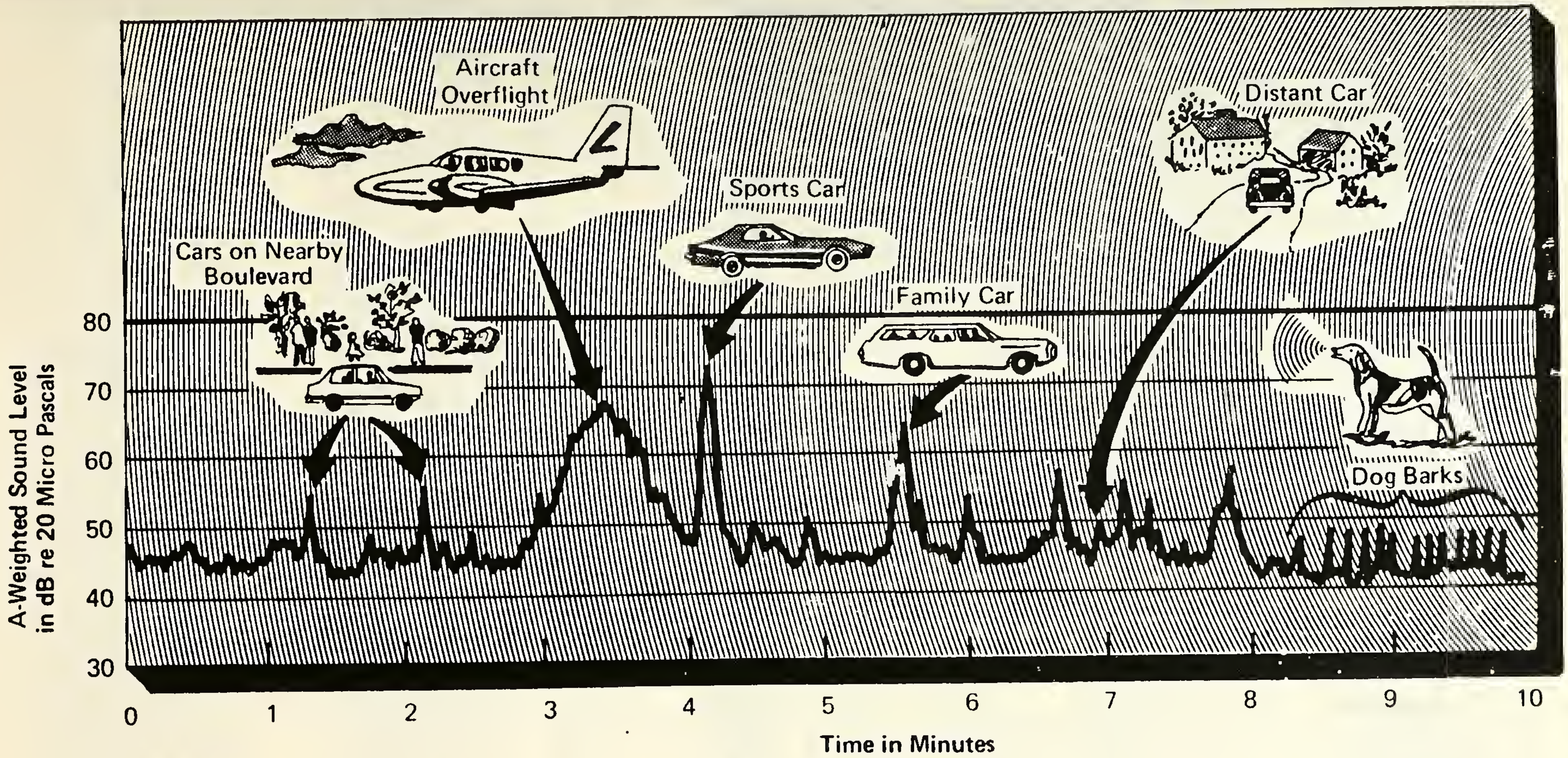


FIGURE 2. TYPICAL OUTDOOR SOUND MEASURED ON A QUIET SUBURBAN STREET

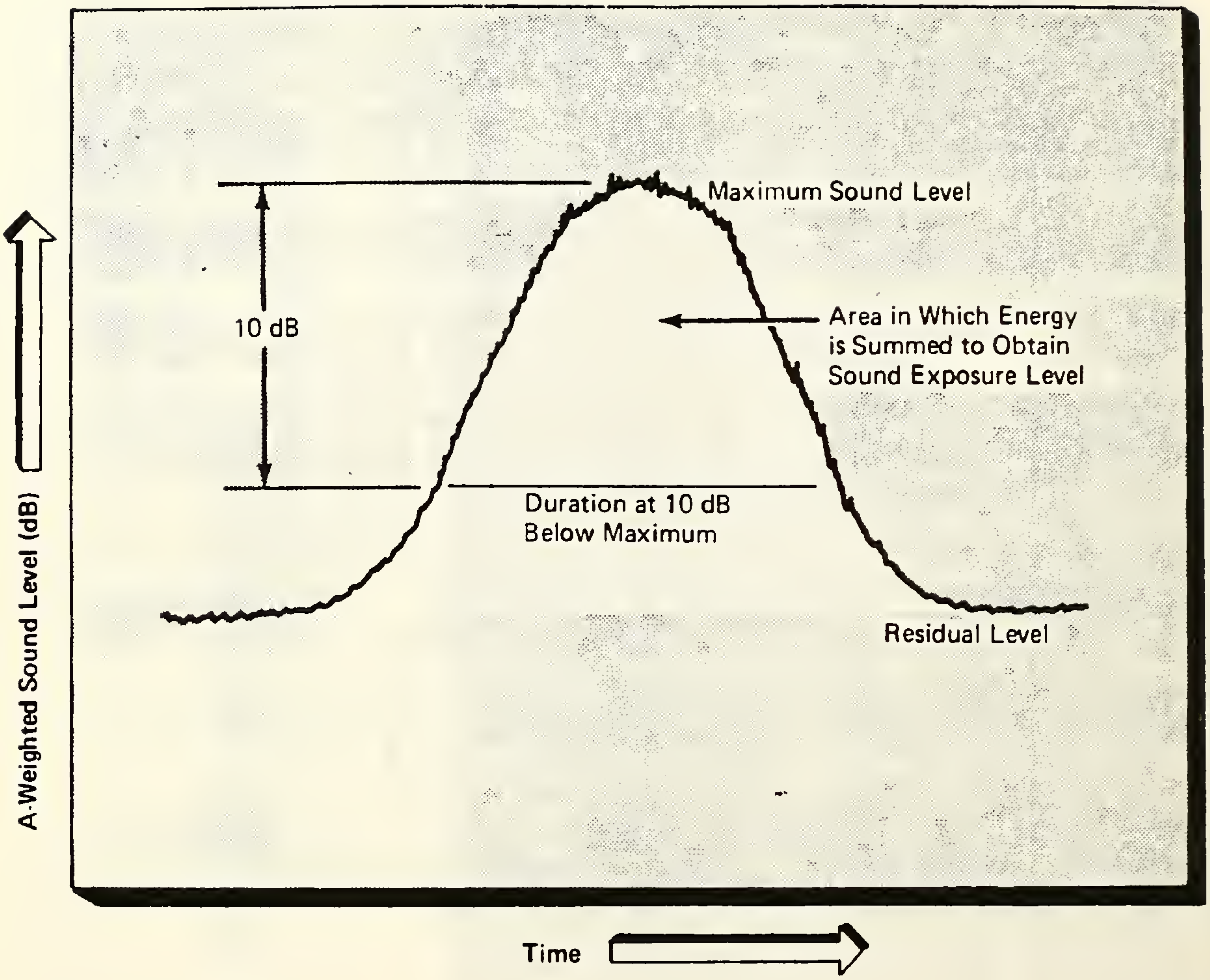

Maximum Sound Level
10 dB
Area in Which Energy is Summed to Obtain Sound Exposure Level
Duration at 10 dB Below Maximum
Residual Level
A-Weighted Sound Level (dB)
Time

FIGURE 3. DESCRIPTION OF THE SOUND OF A SINGLE EVENT

Day-Night Sound Level

The Day-Night Sound Level is the A-weighted equivalent sound level for a 24-hour period with an additional 10 dB weighting imposed on the equivalent sound levels occurring during nighttime hours (10 pm to 7 am). Hence, an environment that has a measured daytime equivalent sound level of 60 dB and a measured nighttime equivalent sound level of 50 dB, can be said to have a weighted nighttime sound level of 60 dB (50 + 10) and an L_{dn} of 60 dB. Examples of measured L_{dn} values are shown in Figure 4. Table I summarizes the use of the four sound descriptors used by EPA.

Table I. Descriptors of Sound*

TYPICAL USE	NAME OF DESCRIPTOR	NATURE OF DESCRIPTOR
To describe steady airconditioning sound in a room or measure maximum sound level during a vehicle passby with a simple sound level meter.	A-weighted Sound Level	The momentary magnitude of sound weighted to approximate the ear's frequency sensitivity.
To describe noise from a moving source such as an airplane, train, or truck.	A-weighted Sound Exposure Level	A summation of the energy of the momentary magnitudes of sound associated with a single event to measure the total sound energy of the event.
To measure average environmental noise levels to which people are exposed.	Equivalent Sound Level	The A-weighted sound level that is "equivalent" to an actual time varying sound level, in the sense that it has the same total energy for the duration of the sound.
To characterize average sound levels in residential areas throughout the day and night.	Day-Night Sound Level	The A-weighted equivalent sound level for a 24-hour period with 10 decibels added to nighttime sounds (10 pm - 7 am).

*The unit for all descriptors is the decibel.

LEVELS OF ENVIRONMENTAL NOISE IN THE UNITED STATES

In residential areas of the United States, major contributions to outdoor noise come from transportation, industrial, construction, human and animal sources. Inside homes, appliances, radio and television, as well as people and animals, are predominant noise sources. On the job, workplace equipment can create moderate to extremely high levels of noise. The daily noise exposure of people depends on how much time they spend in different outdoor and indoor locations and on the noise environments in these places. Typical daily exposure patterns are discussed in this section, following short descriptions of outdoor and indoor levels of environmental noise throughout the United States.

Outdoor Levels

The noise environment outside residences in the United States can be highly variable. As seen in Figure 4, outdoor Day-Night Sound Levels in different areas vary over a range of 50 dB. Levels occur as low as L_{dn} = 30 to 40 dB in wilderness areas and as high as L_{dn} = 85 to 90 dB in urban areas.

Most Americans live in areas with a much smaller ranger of outdoor noise levels. Figure 5 shows that for urban dwellers (roughly 135 million people, more than half the U.S. population), 87% live in areas of L_{dn} = 48 and higher from traffic noise alone. Most of the other 13% of the urban population experience lower noise levels than those of Figure 5. Figure 5 also shows that nearly half of the urban population live in areas exposed to traffic sounds that range over only 5 dB (L_{dn} = 55 to 60 dB). Rural populations enjoy average outdoor sound levels generally lower than L_{dn} = 50 dB.

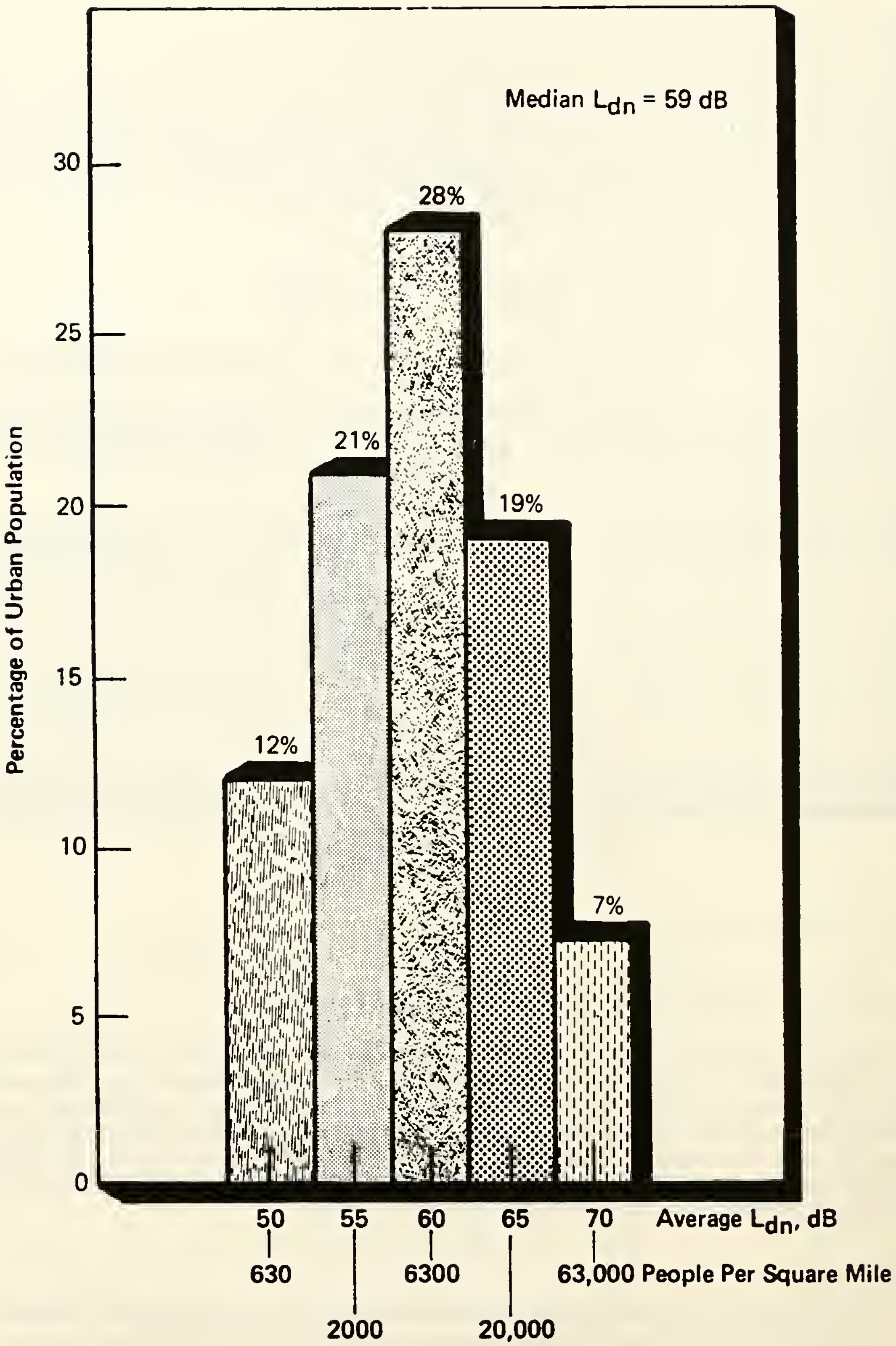


FIGURE 5. ESTIMATED PERCENTAGE OF URBAN POPULATION EXPOSED TO OUTDOOR DAY-NIGHT SOUND LEVELS DUE TO TRAFFIC

APPENDIX B

DESCRIPTION OF 24-HOUR NOISE MONITORING PROCEDURE

The 24-hour noise monitoring program took place from 8:00 AM to 16:00 on August 14, 1979, and from 16:00 on August 15 to 7:50 on August 16. The monitoring was ceased at 16:00 on August 14 due to a loud siren-type alarm sounding in the immediate vicinity of the site. This caused uncommonly high noise levels for the time period.

The 1945 GenRad Noise Meter is capable of recording and analyzing noise for three separate time periods each time it is run. For this study, three 1-hour periods were programmed for each day-time run. At the end of the three hours, values were recorded from a digital read-out. The meter was set for a fast response time.

During the night, the meter was set for three runs; 22:10 to 00:10, 00:10 to 6:10 and 6:10 to 7:10.

The 1945 GenRad noise meter records 16 noise parameters as shown on Table B-1. Comments regarding specific noise inputs during the monitoring are included on the Table.

COPLEY NOISE MEASUREMENTS   HARCOURT ST.   OBSERVERS: MTB, STM

HOUR	L_{max}	$L_{0.1}$	$L_{1.0}$	L_{10}	L_{50}	L_{90}	L_{99}	L_{min}	L_{eq}	L_{20}	L_{5}	L_{2}	.5/8	8/24	1/24	.5/24	COMMENTS
8:00-9:00	79	77	73	65	61	59	58	57	63	63	67	70	66	62	68	70	8/14/79
9:00-10:00	83	80	76	65	60	58	57	55	64	63	69	73	68	61	70	73	mowing grass on site
10:00-11:00	82	78	73	63	59	56	55	54	62	61	66	70	66	60	67	70	
11:05-12:05	95	81	74	63	58	53	52	50	63	61	65	69	64	60	65	69	garbage truck
12:05-13:05	81	77	72	62	56	54	53	52	61	59	66	70	65	58	67	70	
13:05-14:05	99	76	69	61	56	54	52	50	62	59	64	67	63	58	65	67	
14:08-15:08	80	77	70	62	56	54	53	52	60	59	65	68	64	58	65	68	
15:08-16:08	86	80	71	60	56	55	54	51	60	58	63	67	62	57	63	87	
16:00-17:00	91	86	79	71	63	60	59	58	68	68	73	76	73	65	74	76	8/15/79
17:00-18:00	88	85	81	71	63	60	58	56	69	68	74	79	73	66	75	78	front end Loader at 50' for 2-3 min
18:00-19:00	90	89	78	68	61	58	56	55	67	64	71	75	71	62	72	74	
19:30-20:00	80	78	74	68	60	56	54	52	64	65	70	73	69	62	71	73	
20:00-21:00	82	78	72	63	56	53	52	50	61	60	66	70	65	58	67	69	Rain @ 20:45
21:00-22:00	84	82	75	65	56	52	50	49	64	61	68	72	67	58	69	72	Rain Stopped
22:10-00:10	79	78	72	63	57	55	53	50	61	61	66	69	65	59	67	69	
00:10-6:10	91	83	72	61	55	51	49	48	61	58	63	68	63	57	64	67	8/16/79
6:10-7:10	86	81	74	67	62	60	58	56	65	65	69	72	68	63	69	71	
7:20-7:50	84	83	79	72	66	62	61	60	69	70	75	78	74	67	76	78	

TABLE B-1

1945 Community Noise Analyzer

- **on-site readout of:**
  L exceedance levels, L_{dn}, and L_{eq}
- **does not require tape recorders or calculators**
- **battery power eliminates ac line requirements**
- **low-cost, optional weatherproof microphone system**
- **weatherproof security enclosure available**
- **analysis durations from 10 minutes to 24 hours available**
- **data inhibit available**

A stand-alone instrument The GR 1945 is designed to satisfy the need for a low-cost, easy-to-use community noise analyzer, without the need for tape recorders, calculators, or computers. It monitors noise levels for up to three sequential time periods having selectable durations from 30 minutes to 24 hours, or 10 minutes to 8 hours (1945-9006), and automatically computes and stores L exceedance levels, L_{dn}, and L_{eq} (optional), for each time period. Answers to the computed levels are instantly available at the push of appropriate pushbuttons. The 1945 displays the levels on an easy-to-read digital display. Sound-level measurements of existing ambient levels can also be made at the push of a button.

High reliability Unlike electro mechanical systems that use a tape recorder for data storage, the 1945's functions are completely electronic. It does not have moving mechanical parts that are prone to wear out and which may malfunction in environmental extremes. In addition, the concern of proper recording on expensive certified tapes during widely fluctuating temperature extremes is eliminated.

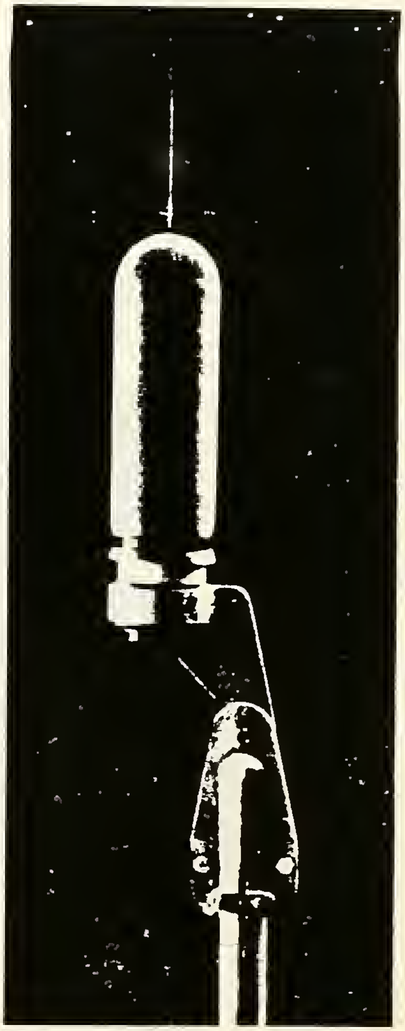
The 1945 has a 100-dB dynamic range to ensure that data will not be lost during wide variations in noise levels. This capability, plus the completely automatic electronic operation of the 1945, contributes to the high reliability of its answers.

Economy and ease of use When you buy the 1945 and the microphone of your choice, you are ready to begin measuring and analyzing noise without further equipment expense. There is no need to purchase a programmable calculator, a computer, or expensive certified tape cassettes. You need only select the measurement site and follow the simple steps summarized in the instruction manual.

Security and Environmental Protection For optimum performance and protection of the 1945 at unattended measurement locations a weatherproof microphone system and weatherproof enclosure are offered as accessories.

The 1945 9730 Weatherproof Microphone System is a complete weatherproof system for outdoor noise monitoring. It is designed to protect its integral 1560-P42 Preamplifier and a microphone (not included) in an outdoor environment. The windscreen system provided protects the microphone from damage and reduces the effect of wind on the noise measurement. A GR electret-condenser or ceramic microphone should be used with this system (see Specifications section).

The 1945-9640 Weatherproof Enclosure provides a weatherproof and vandal resistant shelter for the 1945 analyzer. It is supplied with a bracket for mounting to a pole or building and a base for free standing operation. The enclosure is fabricated from heavy gauge aluminum and has a tumbler lock for security.



SPECIFICATIONS

ANALYZER

Sensitivity Range: Microphone input can be directly calibrated with microphone-preamplifier combinations having sensitivity of 35 to 45 dB re 1 V/N/m² (55 to 65 dB re 1 V/μbar). AUX INPUT: (For use with 1935 Cassette Recorder) 0.5 V rms corresponds to 120 dB.

Maximum Detected Level: 120 dB rms, provides 14-dB crest factor.

Minimum Detected Level: 5 dB above typical noise floor, using 1972-9600 or 1560-P42 Preamplifier with indicated microphone as follows:

Microphone input with	A	C	FLAT
GR 1962 Microphone	27 dB	30 dB	40 dB
GR 1961 Microphone	23 dB	26 dB	38 dB
GR 1971 Microphone	25 dB	25 dB	29 dB
AUX Input	27 dB	26 dB	29 dB

Input Impedance: 20 kΩ.

Maximum Safe Input Voltage: ±15 V peak ac, 35 V dc.

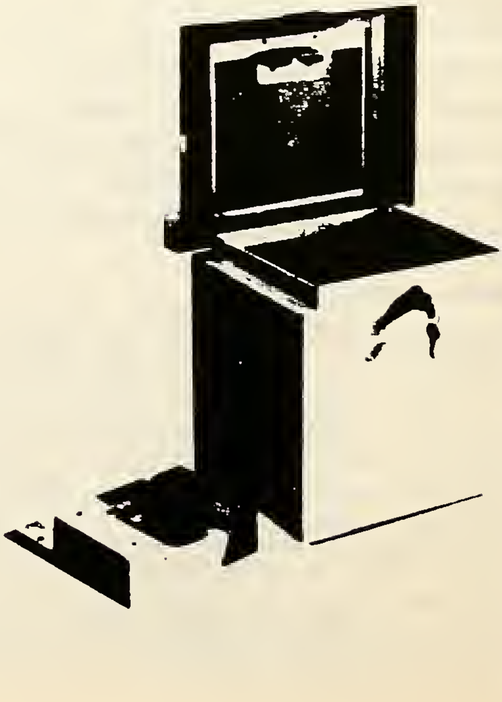
Weighting: A, C, or FLAT selected by front panel slide switch. A and C per ANSI S1.4-1971 Type 1 and IEC 179-1973. FLAT response +0.5, −3 dB 10 Hz to 25 kHz re 1 kHz. D weighting optionally available, consult factory.

Detector: True rms with 14-dB crest-factor capacity at 120-dB level. FAST or SLOW dynamic detection characteristic per ANSI S1.4-1971 Type 1 and IEC 179-1973 selected by front panel slide switch.

Statistical Analysis: RESOLUTION: 1 dB. LINEARITY: 0.25 dB. ANALYSIS DURATION: Selected by front panel switch; choices listed below. NUMBER OF SAMPLES: Function of analysis duration as follows:

Analysis Duration	Number of Samples
4, 6, 8, 12 or 24 hours	65528
2 or 3 hours	32764
1 hour	16382
½ hour	8191

NUMBER OF ANALYSES: One, two or three independent consecutive analyses may be selected. L_{eq} ANALYSIS: When the 1945 is supplied with L_{eq} option, each sample is also used to compute L_{eq}, the equivalent continuous level, over the analysis period, or L_{dn} on a 24-hour run. L_{dn} is identical to L_{eq} except that a 10-dB penalty is added to all levels from 10:00 p.m. to 7:00 a.m. L_{eq} may be enabled on 24-h run by changing internal jumper prior to analysis. ANALYSIS TIMING: Start of first analysis may be delayed up to 24 hours from initial set up by use of internal clock.



Display: LEVEL dB: Current sound level may be displayed digitally with 1-dB resolution before, during or after analysis. It is updated every 0.22 second. EXCEEDANCE LEVELS: After analysis is complete, desired exceedance levels are pushbutton selected. The following exceedance levels are available: $L_{0.1}$, L_1, L_2, L_5, L_{10}, L_{20}, L_{50}, L_{90}, L_{99}, L_{min}, L_{max}. Also selectable are $L_{33.3}$, $L_{4.17}$, $L_{2.08}$, $L_{6.25}$, corresponding to HUD Circular 1390.2 requirements of level exceeded 8 hours of 24, 1 hour of 24, ½ hour of 24 and ½ hour of 8 hours. EQUIVALENT CONTINUOUS LEVEL: After analysis is complete, L_{eq} (or L_{osha}) is selected by pushbutton. See "L_{eq} Analysis" above.

Data Output (electrical): Remote output connector provides the following: DC OUTPUT: 4.8 V dc behind 5 kΩ corresponds to 120-dB level, output linear at 40 mv/dB over an 80 to 98-dB dynamic range (limited only by internal noise for microphone and weighting selected). DIGITAL: Cumulative distribution, with 1-dB resolution, available in serial form with clocks for decoding. Signals to identify analysis complete and selected memory are provided. All digital signals are buffered CMOS outputs, ≃8 V logic levels. EXTERNAL POWER: Input from external battery or power supply at 8-15 V, 70 mA max, allows extended operating periods. Input has polarity reversal protection.

Environmental: TEMPERATURE: −10 to +60°C operating, −40 to +55°C storage (batteries installed), −40 to +75°C storage (batteries removed). HUMIDITY: 0 to 90% RH operating. VIBRATION: 0.030" excursion 10-55 Hz.

Supplied: Screwdriver to adjust microphone CAL pot, two battery packs, 8 alkaline "D" cells, plug for microphone input, cable for remote output connector, instruction sheet.

Available: 1945-9640 Weatherproof Enclosure, 1945-9730 Weatherproof Microphone System, for outdoor use. Preamplifier, electret-condenser and ceramic microphones, cables and windscreens also available.

Power: 8 "D" cells provide 75 hours' continuous operation or permit 24 hours' running time and 1 week of idling memory contents at 25°C.

Mechanical: DIMENSIONS (wxhxd): Models 1945-9700 and -9710: 8.5x10.75x9.38 in. (216x273x238 mm). WEIGHT: Model 1945-9700: 16.5 lb (7.5 kg) net; model 1945-9710: 15.5 lb (7.1 kg) net.

---

962 ½-inch electret-
ondenser
nicrophone

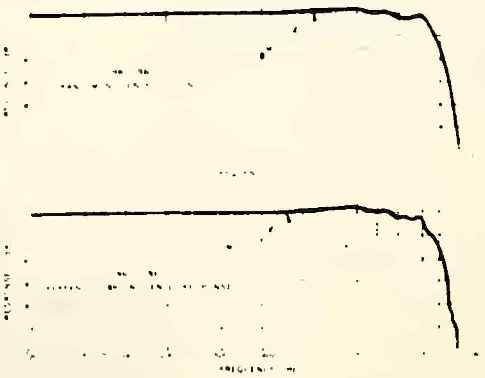
equency: Curves show typical
sponse and guaranteed limits;
dividual response curve sup-
ied with each microphone.
low 20 Hz, the microphone
typically flat + 1 dB down to
Hz relative to 1-kHz level.
crophone is essentially omni
rectional.

nsitivity Level: Nominal: −40
re 1 V/Pa (−60 dB re 1 V/μ
r). Temperature Coefficient:
.010 dB/°C typically from −20
+55°C at 1 kHz. Maximum
und-Pressure Level: 170 dB
20 μPa absolute max.

pedance: Nominal 25 pF at
°C and 1 kHz.

vironment: −40 to +60°C
d 0 to 99% RH operating; 1-
ar exposure in an environment of +55°C and 90% RH causes negligible sensitivity change.

Mechanical: Terminals: Coaxial, with 0.460-60 thread. Dimensions: 0.500 ±0.001 in. dia x 0.615 in. long (12.70 ±0.0254x 15.62 mm). Weight: 0.25 oz. (7 g) net, 1 lb (450 g) shipping



Typical performance
with 1560-P42 and 1972-9600 Preamplifiers (Unity Gain)

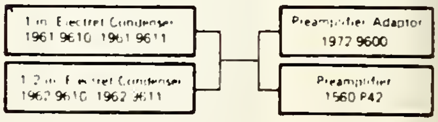
Microphone	Frequency Range	"System Sensitivity re 1 V/Pa	Dynamic Range* re 20 μPa
1962-9610	15 Hz to 19 kHz	−40 dB	30 to 145 dB
1962-9611	15 Hz to 24 kHz	−40 dB	30 to 145 dB

* A weighted noise level to maximum rms sinewave signal without clipping

Description	Catalog Number
1962 Electret-Condenser Microphones	
Flat random-incidence response, ½-inch	1962-9610
Flat perpendicular-incidence response, ½-inch	1962-9611

- For electret-condenser, air-condenser, and ceramic microphones and vibration pickups

The 1560 P42 Preamplifier is a high input impedance, low-noise preamplifier. It is particularly well suited for amplification of the output of capacitive sources, such as electret-condenser, air-condenser, and ceramic microphones and piezoelectric vibration pickups. It is an excellent choice for use with GR sound-level meters and analyzers when a long cable must be used between the microphone and the instrument. It is also a useful probe amplifier for other electrical signals where high input impedance and low noise are necessary. For example, it can increase the sensitivity and input impedance of analyzers, recorders, amplifiers, null detectors, counters, frequency meters, voltmeters, and oscilloscopes. Output from the preamplifier is through a removable 3-wire shielded cable and the required dc supply voltage is applied from one of the wires to ground.



CONDENSED SPECIFICATIONS

Gain: 1:1 or 10:1 (20 dB) ±0.3 dB at 25° C, slide-switch controlled, < 0.3-dB gain change, from that at 25° C, from −30 to +65° C.

Frequency Response (at 1-V rms open-circuit output behind 600 Ω, −30 to +55° C):

	1:1 Gain	10:1 Gain
3 Hz		
	±3 dB	±3 dB
5 Hz		
	±1 dB	±1.5 dB
20 Hz		
	±0.25 dB	±0.3 dB
100 kHz		
	±1 dB	±2 dB
300 kHz		
500 kHz		

Impedance: Input: ≈ 2 GΩ in parallel with <6 pF; driven shield reduces input-capacitance loading for condenser microphones. Output: ≈15 Ω in series with 3.3 μF.

Mechanical: Dimensions (less cable): 6.75 in. (170 mm) long x 0.5 in. (13 mm) dia. Weight (with cable): 1 lb (0.5 kg) net, 3 lb (1.4 kg) shipping.

Description	Catalog Number
1560-P42 Preamplifier	**1560-9642**

GenRad's 1987 Minical Sound-Level Calibrator is ideal for routine sensitivity checks. It produces a 1000-Hz signal at levels of 94 and 114 dB and can be used with all the measurement microphones listed for the Omnical. Small enough to fit in the palm of your hand, the Minical incorporates the same design features for accuracy and stability as those noted for the 1986.

GenRad's 1987 Minical Sound-Level Calibrator is designed for quick daily checks of sound-level meters and other acoustic instruments where calibration should be verified before and after measurements.

APPENDIX C

HUD REGULATIONS

federal register

Thursday
July 12, 1979

Part V

Department of Housing and Urban Development

Office of the Secretary

Environmental Criteria and Standards

HOUSING AND URBAN DEVELOPMENT

24 CFR Part 51

[Docket No. R-79-595]

Environmental Criteria and Standards

AGENCY: Department of Housing and Urban Development.

ACTION: Final rule.

SUMMARY: This final rule adds a new Part 51, Environmental Criteria and Standards to Title 24 of the CFR. The rule sets forth Subparts A and B covering General Provisions and Noise Abatement and Control respectively.

EFFECTIVE DATE: August 13, 1979.

FOR FURTHER INFORMATION CONTACT: James F. Miller or Gretchen Van Hyning, Office of Environmental Quality, Room 7266, U.S. Department of Housing and Urban Development, 451 7th Street, SW., Washington, 20410 D.C. (202) 755-8909 (this is not a toll-free number).

SUPPLEMENTAL INFORMATION: A Notice of Proposed Rulemaking was published on December 27, 1978 (43 FR 60396) indicating that HUD proposed to add a new Part 51, Environmental Criteria and Standards, to Title 24 of the CFR. The proposed rule would include Subpart A, General Provisions, and Subpart B, Noise Abatement and Control. The Notice invited public comment until January 26, 1979.

Subpart B establishes Departmental standards, requirements, and guidelines on noise abatement and control, replacing and revising the noise policies, standards and procedures previously set forth in HUD Circular 1390.2, which is cancelled when this final rule becomes effective.

Subpart B converts the existing noise policy to regulation format and makes revision and improvements intended to make the policy more flexible and consistent with other Federal agencies' noise programs. Revisions to the current policy (1) bring into conformity, through the use of the day-night average sound level, separate standards and measurements for aircraft and non-aircraft noise; (2) afford Field Offices more flexibility in implementing the policy thus reducing the number of cases having to come into the Region and Headquarters Offices; (3) remove the dual exterior and interior standards, hence, if exterior noise levels are found to be acceptable, the interior noise will be considered acceptable using normal building techniques; and (4) allow easy use of already existing data, particularly from FHWA and DOD. The standards apply primarily to HUD support for new residential construction in certain noise zones—as does the existing policy.

Overall, the comments indicated strong support for the revisions to the noise policy, particularly the use of the day-night average sound level descriptor and the acceptability thresholds used by the Department. The one topic which generated substantial discussion and a divergence of opinion was the methodology for describing "loud implusive sounds."

The following discussion summarizes the significant comments and the changes that were made in the final rule.

1. *Use of the Day-Night Average Sound Level (DNL) to Describe Noise.*—Of the 18 responses, 15 commented on the proposed noise descriptor. Only two of these expressed reservations (one Federal agency and one industry group) about use of the day-night average sound level; these two comments were directed to use of a nighttime penalty in DNL. Both parties recommended substituting a computer based model which itself, among other things, incorporates a nighttime penalty. The same agency has also issued advisory materials containing noise metrics which include the nighttime correction.

The proposed methodology for describing noise has been widely used to relate individual and community reaction to aircraft and road traffic noise, to predict the likelihood and the severity of interference with speech and sleep, and to correlate hearing loss with noise exposure. The simple concept of average sound level must be somewhat refined to account for the fact, documented by most community response and public opinion surveys, that the same noise level is considered more disturbing or annoying during the nighttime than during daytime. Not only do the requirements for undisturbed sleep and relaxation make a lower nighttime noise level desirable, but the exterior background noise level in most communities drops during the night by 10 dB or more and reduced activity inside homes contributes to a general lowering of interior noise levels. Consequently, intrusive noises are more disturbing during the night. To assess nighttime noise events in a way that accounts for their increased potential for causing disturbances a weighting factor of 10 dB is applied to all nighttime noises; i.e., nighttime noises are treated as if they were 10 dB noiser than they actually are. The need for a nighttime correction has also received international concensus through the International Organization for Standardization (ISO).

In view of the acceptance and supp for the DNL descriptor, HUD is publishing the final rule using the DNL with the nighttime correction for application of the standards.

2. *Proposed Standards.*—Most responses indicated the appropriatene of the general goals and levels propose by HUD. Two responses however indicated concern that noise transmitt within multifamily dwellings was not addressed. This problem is however covered in Section 51.101(a)(10); the relevant reference to the Minimum Property Standards for Multifamily Housing is Section 404 on Acoustic Control.

Several comments related to conversion of existing data to DNL. Th conversion factors have been clarified the final rule and the conversion indicates the measures "are approximately equal to" rather than th same. In the final rule one descriptor f aircraft noise was added—(Community Noise Equivalent Level, used in California) and one was deleted (Composite Noise Rating). The Composite Noise Rating methodology was developed in the early 1960's and i subject to error and is used only infrequently and therefore it has been dropped from the final rule (see Section 51.106).

Conversion of highway levels (Sectio 51.106) to DNL is discussed in the National Cooperative Highway Research Program Report No. 173 on "Highway Noise Generation and Control," published by the Transportation Research Board in 1976.

3. *Analysis of Loud Impulsive Sounds.*—Five responses were directed to the methodology for calculating "loud impulsive sounds." The method for characterizing noise from explosions or sonic booms proposed by HUD in Section 103(b) is consistent with the interim procedures of the Department of Defense. HUD recognizes that the subject is currently undergoing technical debate, but no alternative has emerged upon which the technical community has agreed. This method is likely to be applied mostly in rare instances where sites are proposed in the vicinity of artillery firing ranges or other similar activities. In view of the current debate the final rule has been amended, in the text and in the Appendix, to emphasize that this methodology is to be used on an *interim basis*. When a final procedure is adopted by all the concerned Federal agencies, HUD's rule will be changed to incorporate the agreed upon methodology.

4. *Noise Attenuation.*—It was recommended by one reviewer that noise attenuation be expressed in terms of total sound attenuation rather than the requirement for attenuation measures in addition to the attenuation provided by housing as commonly constructed in the area. The results are essentially the same and both approaches have been considered. It was determined that the suggested approach by the reviewer may overstate the requirements while HUD's policy is to state minimum requirements to provide adequate protection at minimum cost. The final rule was changed to indicate that the additional noise attenuation measures are minimum requirements.

5. *Other Comments.*—Several reviewers provided editorial and technical corrections which have been included in the final rule. Some comments were not relevant to the specific rule, while other suggested that the Department prepare documents setting forth the rationale for the HUD standards and provide guidance to local governments. This work is underway, and a revised "Noise Assessment Guidelines" document should be available by the time the rule becomes effective. A technical background report on the policy is also in preparation and will be available at a later date. Two reviewers also suggested that HUD develop a procedure for notifying purchasers of existing properties if noise levels exceed those of the established regulation. HUD does consider noise as a marketability factor in Section 51.101(a)(4) in determining the amount of insurance or other assistance that may be given but does not propose to include a specific additional notification procedure in the appraisal process.

Some reviewers suggested that HUD take a major role in Federal efforts to control noise. HUD is cooperating with the EPA, DOT and DOD in interagency noise programs; these other agencies have responsibility for controlling noise at the source. HUD's regulations are necessarily limited to programs administered by the Department; however, the standards and guidance material should assist local governmental agencies and others in formulating policies to achieve quieter urban environments.

OTHER INFORMATION: A Finding of Inapplicability with regard to Environmental Impact has been prepared in accordance with HUD's environmental procedures. Copies of the statement and findings are available for inspection and copying in the Office of the Rules Docket Clerk, Room 5218, Department of Housing and Urban Development, 451 7th Street, S.W., Washington, D.C. 20410.

Accordingly, Title 24 of the CFR is amended by adding a new Part 51 to read as follows:

PART 51—ENVIRONMENTAL CRITERIA AND STANDARDS

Subpart A—General Provisions

Sec.
51.1 Purpose.
51.2 Authority.
51.3 Responsibilities.
51.4 Program coverage.
51.5 Coordination with environmental clearance requirements.
51.6 [Reserved]

Subpart B—Noise Abatement and Control

51.100 Purpose and authority.
51.101 General policy.
51.102 Responsibilities.
51.103 Criteria and standards.
51.104 Special requirements.
51.105 Exceptions.
51.106 Implementation.

Appendix

Authority: Sec. 7(d), Department of HUD Act (42 U.S.C. 3535(d)).

Subpart A—General Provisions

§ 51.1 Purpose.

The Department of Housing and Urban Development is providing program Assistant Secretaries and administrators and field offices with environmental standards, criteria and guidelines for determining project acceptability and necessary mitigating measures to insure that activities assisted by the Department achieve the goal of a suitable living environment.

§ 51.2 Authority.

This Part implements the Department's responsibilities under the following statutes:

(a) The National Housing Act of 1934 (Pub. L. 73-479) which was enacted "to encourage improvements in housing standards and conditions, to provide a system of mutual mortgage insurance, and for other purposes," thus providing the basis for HUD's Minimum Property Standards (MPS) which have evolved as required by legislation over the past 44 years.

(b) The Housing Act of 1949 (Pub. L. 81-171) which sets forth the national goal of "a decent home and a suitable living environment for every American family," affirmed by the Housing and Urban Development Act of 1968 (Pub. L. 90-448).

(c) The Department of Housing and Urban Development Act of 1965 (Pub. L. 89-174) which provides that the Secretary may make such rules and regulations as may be necessary to carry out functions, powers, and duties, and sets forth, as a matter of national purpose, the sound development of the Nation's communities and metropolitan areas.

(d) The National Environmental Policy Act of 1969 (Pub. L. 91-190) which directs Federal agencies to develop procedures to carry out the purposes of the Act.

(e) Intergovernmental Cooperation Act of 1968 (Pub. L. 90-577) which, under Title IV, directs that Federal programs and projects serve the objectives of appropriate land use for housing, commercial, industrial, governmental, institutional, and other purposes to achieve sound and orderly development of all areas, both urban and rural.

§ 51.3 Responsibilities.

(a) *Assistant Secretary for Community Planning and Development.* The Assistant Secretary for Community Planning and Development shall be responsible for administering environmental regulations, and shall provide oversight, interpretation and guidance, and shall update the regulations as required. The Assistant Secretary shall also maintain liaison with other Federal agencies on matters of environmental policy implementation.

(b) *Assistant Secretary for Policy Development and Research.* The Assistant Secretary for Policy Development and Research shall undertake research and demonstration studies necessary for the technical development of environmental standards, criteria, and implementing techniques as a basis for the development and implementation of environmental regulations. The Assistant Secretary shall also maintain liaison with Federal agencies on related technical matters.

(c) *Other Assistant Secretaries, Administrators, and the General Counsel.* Other Assistant Secretaries, Administrators, and the General Counsel shall:

(1) Incorporate adopted environmental regulations by reference into program regulations, guidance documents, and administrative forms and procedures;

(2) Evaluate the effects of, and compliance with Departmental environmental regulations policy and report significant issues and problems to the Assistant Secretary for Community Planning and Development; and

(3) Identify program areas under their jurisdiction in which additional

environmental regulations are needed, and refer them to the Assistant Secretary for Community Planning and Development.

(d) *Regional Administrators, Area Office Managers and Service Office Supervisors.* Regional Administrators, Area Office Managers and Service Office Supervisors shall assure that adopted environmental regulations are implemented in relation to program decisions and recommendations. They shall also monitor projects to assure that mitigation measures are implemented.

§ 51.4 Program coverage.

Environmental standards shall apply to all HUD actions except where special provisions and exemptions are contained in each Subpart.

§ 51.5 Coordination with environmental clearance requirements.

Environmental standards shall be implemented prior to commitment in the decision-making process and, where environmental clearances are required, the decision points shall be identical. Compliance with HUD environmental standards shall be addressed in the environmental clearance process.

§ 51.6 [Reserved]

Subpart B—Noise Abatement and Control

§ 51.100 Purpose and authority.

(a) *Purpose.* The Department of Housing and Urban Development finds that noise is a major source of environmental pollution which represents a threat to the serenity and quality of life in population centers and that noise exposure may be a cause of adverse physiological and psychological effects as well as economic losses.

It is the purpose of this Subpart to:

(1) Call attention to the threat of noise pollution;

(2) Encourage the control of noise at its source in cooperation with other Federal departments and agencies;

(3) Encourage land use patterns for housing and other noise sensitive urban needs that will provide a suitable separation between them and major noise sources;

(4) Generally prohibit HUD support for new construction of noise sensitive uses on sites having unacceptable noise exposure;

(5) Provide policy on the use of structural and other noise attenuation measures where needed; and

(6) Provide policy to guide implementation of various HUD programs.

(b) *Authority.* Specific authorities for noise abatement and control are contained in:

(1) The Noise Control Act of 1972 (Pub. L. 92-574) which directs Federal agencies to administer their programs in ways which reduce noise pollution.

(2) The Quiet Communities Act of 1978 (Pub. L. 95-609) which amended Pub. L. 92-574.

(3) The General Services Administration, Federal Management Circular 75-2: *Compatible Land Uses at Federal Airfields* prescribes the Executive Branch's general policy with respect to achieving compatible land uses on either public or privately owned property at or in the vicinity of Federal airfields.

(4) Section 1113 of the Housing and Urban Development Act of 1965 (Pub. L. 89-117) directs the Secretary "* * * to determine feasible methods of reducing the economic loss and hardships suffered by homeowners as a result of the depreciation in the value of their properties following the construction of airports in the vicinity of their homes, including a study of feasible methods of insulating such homes from the noise of aircraft."

§ 51.101 General policy.

(a) It is HUD's general policy to provide minimum national standards applicable to HUD programs to protect citizens against excessive noise in their communities and places of residence.

(1) *Comprehensive planning assistance.* HUD requires that grantees give adequate consideration to noise exposures and sources of noise as an integral part of the urban environment in HUD assisted comprehensive planning, as follows:

(i) Particular emphasis shall be placed on the importance of compatible land use planning in relation to airports, highways and other sources of high noise.

(ii) Applicants shall take into consideration HUD environmental standards impacting the use of land as required in 24 CFR Part 600.

(iii) Environmental studies, including noise assessments, are allowable costs.

(2) *Community Development Block Grants.* Recipients of community development block grants under the Housing and Community Development Act of 1974 (Pub. L. 93-383), as amended by the Housing and Community Development Act of 1977 (Pub. L. 95-128), must take into consideration the noise criteria and standards in the environmental review process and consider ameliorative actions when noise sensitive land development is proposed in noise exposed areas. Grant recipients shall address deviations from the standards in their environmental reviews as required in 24 CFR Part 58.

Where CDBG activities are planned in a noisy area, and HUD assistance is contemplated later for housing and/or other noise sensitive activities, the CDBG grantee risks denial of the HUD assistance unless the HUD standards are met. Environmental studies, including noise assessments, are allowable costs.

(3) *HUD support for new construction.* HUD assistance for the construction of new noise sensitive uses is prohibited generally for projects with Unacceptable noise exposures and is discouraged for projects with Normally Unacceptable noise exposure. (Standards of acceptability are contained in § 51.103(c).) This policy applies to all HUD programs providing assistance, subsidy or insurance for housing, college housing, mobile home parks, nursing homes, hospitals, and all programs providing assistance or insurance for land development, new communities, redevelopment or any other provision of facilities and services which are directed to making land available for housing or noise sensitive development. The policy does not apply to research demonstration projects which do not result in new construction or reconstruction, flood insurance, interstate land sales registration, or any action or emergency assistance under disaster assistance programs which are provided to save lives, protect property, protect public health and safety, remove debris and wreckage, or assistance provided that has the effect of restoring facilities substantially as they existed prior to the disaster.

(4) *HUD support for existing construction.* Noise exposure by itself will not result in the denial of HUD support for the resale and purchase of otherwise acceptable existing buildings. However, environmental noise is a marketability factor which HUD will consider in determining the amount of insurance or other assistance that may be given.

(5) *HUD support of modernization and rehabilitation.* For modernization projects located in all noise exposed areas, HUD shall encourage noise attenuation features in alterations. For major or substantial rehabilitation projects in the Normally Unacceptable and Unacceptable noise zones, HUD actively shall seek to have project sponsors incorporate noise attenuation features, given the extent and nature of the rehabilitation being undertaken and the level or exterior noise exposure. In

Unacceptable noise zones. HUD shall strongly encourage conversion of noise-exposed sites to land uses compatible with the high noise levels.

(6) *Research, guidance and publications.* HUD shall maintain a continuing program designed to provide new knowledge of noise abatement and control to public and private bodies, to develop improved methods for anticipating noise encroachment, to develop noise abatement measures through land use and building construction practices, and to foster better understanding of the consequences of noise. It shall be HUD's policy to issue guidance documents periodically to assist HUD personnel in assigning an acceptability category to projects in accordance with noise exposure standards, in evaluating noise attenuation measures, and in advising local agencies about noise abatement strategies. The guidance documents shall be updated periodically in accordance with advances in the state-of-the-art.

(7) *Construction equipment, building equipment and appliances.* HUD shall encourage the use of quieter construction equipment and methods in population centers, the use of quieter equipment and appliances in buildings, and the use of appropriate noise abatement techniques in the design of residential structures with potential noise problems.

(8) *Exterior noise goals.* It is a HUD goal that exterior noise levels do not exceed a day-night average sound level of 55 decibels. This level is recommended by the Environmental Protection Agency as a goal for outdoors in residential areas. The levels recommended by EPA are not standards and do not take into account cost or feasibility. For the purposes of this regulation and to meet other program objectives, sites with a day-night average sound level of 65 and below are acceptable and are allowable (see Standards in § 51.103(c)).

(9) *Interior noise goals.* It is a HUD goal that the interior auditory environment shall not exceed a day-night average sound level of 45 decibels. Attenuation measures to meet these interior goals shall be employed where feasible. Emphasis shall be given to noise sensitive interior spaces such as bedrooms. Minimum attenuation requirements are prescribed in § 51.104(a).

(10) *Acoustical privacy in multifamily buildings.* HUD shall require the use of building design and acoustical treatment to afford acoustical privacy in multifamily buildings pursuant to requirements of the Minimum Property Standards.

§ 51.102 Responsibilities.

(a) *Authority to approve projects.* (1) Decisions on proposed projects with acceptable noise exposures shall be delegated to the program personnel within field offices, including projects where increased noise levels are considered acceptable because of non-acoustic benefits under § 51.105(a). Field office program personnel may also approve projects in normally unacceptable noise exposed areas where adequate sound attenuation is provided and where the project does not require an Environmental Impact Statement under § 51.104(b).

(2) Other approvals in normally unacceptable noise exposed areas require the concurrence of the Regional Administrator.

(3) Requests for approvals of projects or portions of projects with unacceptable noise exposures shall be referred through the Regional Office to the Assistant Secretary for Community Planning and Development for approval pursuant to § 51.104(b).

(4) In cases where the Regional Administrator determines that an important precedent or issue is involved, such cases shall be referred with recommendations to the Assistant Secretary for Community Planning and Development.

(b) *Surveillance of noise problem areas.* Appropriate field staff shall maintain surveillance of potential noise problem areas and advise local officials, developers, and planning groups of the unacceptability of sites because of noise exposure at the earliest possible time in the decision process. Every attempt shall be made to insure that applicants' site choices are consistent with the policy and standards contained herein.

(c) *Notice to applicants.* At the earliest possible stage, HUD program administrators shall:

(1) Determine the suitability of the acoustical environment of proposed projects;

(2) Notify applicants of any adverse or questionable situations; and

(3) Assure that prospective applicants are apprised of the standards contained herein so that future site choices will be consistent with these standards.

(d) *Technical assistance.* Technical assistance in the measurement, estimation, interpretation, or prediction of noise exposure is available from the Office of Community Planning and Development and the Office of Policy Development and Research. Field office questions shall be forwarded through the Regional Office to the Assistant Secretary for Community Planning and Development or his designee.

(e) *Interdepartmental coordination.* Regional Administrators shall foster appropriate coordination between field offices and other departments and agencies, particularly the Environmental Protection Agency, the Department of Transportation, Department of Defense representatives, and the Veterans Administration. HUD staff shall utilize the acceptability standards in commenting on the prospective impacts of transportation facilities and other noise generators in the Environmental Impact Statement review process.

§ 51.103 Criteria and standards.

These standards apply to all programs as indicated in § 51.101.

(a) *Measure of external noise environments.* The magnitude of the external noise environment at a site is determined by the value of the day-night average sound level produced as the result of the accumulation of noise from all sources contributing to the external noise environment at the site. Day-night average sound level, abbreviated as DNL and symbolized as L_{dn}, is the 24-hour average sound level, in decibels, obtained after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m. Mathematical expressions for average sound level and day-night average sound level are stated in the Appendix.

(b) *Loud impulsive sounds.* On an interim basis, when loud impulsive sounds, such as explosions or sonic booms, are experienced at a site, the day-night average sound level produced by the loud impulsive sounds alone shall have 8 decibels added to it in assessing the acceptability of the site (see Appendix). Alternatively, the C-weighted day-night average sound level (L_{Cdn}) may be used without the 8 decibel addition, as indicated in Section 51.106(a)(3).

Methods for assessing the contribution of loud impulsive sounds to day-night average sound level at a site and mathematical expressions for determining whether a sound is classed as "loud impulsive" are provided in the Appendix.

(c) *Exterior standards.* The degree of acceptability of the noise environment at a site is determined by the sound levels external to buildings or other facilities containing noise sensitive uses. The standards shall usually apply at a location 2 meters (6.5 feet) from the building housing noise sensitive activities in the direction of the predominant noise source. Where the building location is undetermined, the standards shall apply 2 meters (6.5 feet) from the building setback line nearest to the predominant noise source. The standards shall also apply at other locations where it is determined that quiet outdoor space is required in an area ancillary to the principal use on the site.

The noise environment inside a building is considered acceptable if (a) the noise environment external to the building complies with these standards, and (b) the building is constructed in a manner common to the area or, if of uncommon construction, has at least the equivalent noise attenuation characteristics.

Site Acceptability Standards

	Day-night average sound level (in decibels)	Special approvals and requirements
Acceptable	Not exceeding 65 dB(1)	None
Normally Unacceptable	Above 65 dB but not exceeding 75 dB	Special Approvals (2) Environmental Review (3) Attenuation (4)
Unacceptable	Above 75 dB	Special Approvals (2) Environmental Review (3) Attenuation (5)

Notes.—(1) Acceptable threshold may be shifted to 70 dB in special circumstances pursuant to Section 51 105(a).

(2) See Section 51 104(b) for requirements.

(3) See Section 51 104(b) for requirements.

(4) 5 dB additional attenuation required for sites above 65 dB but not exceeding 70 dB and 10 dB additional attenuation required for sites above 70 dB but not exceeding 75 dB (See Section 51 104(a).)

(5) Attenuation measures to be submitted to the Assistant Secretary for CPD for approval on a case-by-case basis.

§ 51.104 Special requirements.

(a) *Noise attenuation.* Noise attenuation measures are those required in addition to attenuation provided by buildings as commonly constructed in the area, and requiring open windows for ventilation. Measures that reduce external noise at a site shall be used wherever practicable in preference to the incorporation of additional noise attenuation in buildings. Building designs and construction techniques that provide more noise attenuation than typical construction may be employed also to meet the noise attenuation requirements.

(1) *Normally Unacceptable noise zone.* Approvals in this zone require a minimum of 5 decibels additional sound attenuation for buildings having noise-sensitive uses if the day-night average sound level is greater than 65 decibels but does not exceed 70 decibels, or a minimum of 10 decibels of additional sound attenuation if the day-night average sound level is greater than 70 decibels but does not exceed 75 decibels.

(2) *Unacceptable noise zone.* Noise attenuation measures require the approval of the Assistant Secretary for Community Planning and Development. (See § 51.104(b)(2).)

(b) *Special Approvals and Environmental Review Requirements.* Environmental clearances shall be conducted pursuant to the requirements of HUD's Departmental Policies, Responsibilities and Procedures for Protection and Enhancement of Environmental Quality (38 FR 19182 as amended) or other environmental regulations which may be issued by the Department. The Special Clearance and Environmental Impact Statement (EIS) threshold requirements are hereby modified for all projects proposed in the Normally Unacceptable and Unacceptable noise exposure zones as follows:

(1) *Normally Unacceptable noise zone.* (i) All projects located in the Normally Unacceptable Noise Zone require a Special Environmental Clearance except an EIS is required for a proposed project located in a largely undeveloped area, or where the HUD action is likely to encourage the establishment of incompatible land use in this noise zone.

(ii) When an EIS is required, the concurrence of the Regional Administrator is also required before a project can be approved. For the purposes of this paragraph, an area will be considered as largely undeveloped unless the area within a 2-mile radius of the project boundary is more than 50 percent developed for urban uses and infrastructure (particularly water and sewers) is available and has capacity to serve the project.

(iii) All other projects in the Normally Unacceptable zone require a Special Environmental Clearance, except where an EIS is required for other reasons pursuant to HUD environmental policies.

(2) *Unacceptable noise zone.* An EIS is required prior to the approval of projects with unacceptable noise exposure. Projects in or partially in an Unacceptable Noise Zone shall be submitted through the Regional Administrator to the Assistant Secretar for Community Planning and Development for approval. The Assistant Secretary may waive the EIS requirement in cases where noise is the only environmental issue and no outdoor sensitive activity will take plac on the site. In such cases, a Special Environmental Clearance is required.

§ 51.105 Exceptions.

(a) *Flexibility for non-acoustic benefits.* Where it is determined that program objectives cannot be achieved on sites meeting the acceptability standard of 65 decibels, the Acceptable Zone may be shifted to L_{dn} 70 on a case-by-case basis if all the following conditions are satisfied:

(1) The project does not require an Environmental Impact Statement under provisions of section 104(b)(1) and noise is the only environmental issue.

(2) The project has received a Special Environmental Clearance and has received the concurrence of the Environmental Clearance Officer.

(3) The project meets other program goals to provide housing in proximity to employment, public facilities and transportation.

(4) The project is in conformance with local goals and maintains the character of the neighborhood.

(5) The project sponsor has set forth reasons, acceptable to HUD, as to why the noise attenuation measures that would normally be required for new construction in the L_{dn} 65 to L_{dn} 70 zone cannot be met.

(6) Other sites which are not exposed to noise above L_{dn} 65 and which meet program objectives are generally not available.

The above factors shall be documented and made part of the project file.

§ 51.106 Implementation.

(a) *Use of available data.* HUD field staff shall make maximum use of noise data prepared by others when such data are determined to be current and adequately projected into the future and are in terms of the following:

(1) *Sites in the vicinity of airports.* The noise environment around airports is described sometimes in terms of Noise Exposure Forecasts, abbreviated as NEF or, in the State of California, as

Community Noise Equivalent Level, abbreviated as CNEL. The noise environment for sites in the vicinity of airports for which day-night average sound level data are not available may be evaluated from NEF or CNEL analyses using the following conversions to DNL:

$DNL \approx NEF + 35$
$DNL \approx CNEL$

(2) *Sites in the vicinity of highways.* Highway projects receiving Federal aid are subject to noise analyses under the procedures of the Federal Highway Administration.

Where such analyses are available they may be used to assess sites subject to the requirements of this standard. The Federal Highway Administration employs two alternate sound level descriptors: (a) The A-weighted sound level not exceeded more than 10 percent of the time for the highway design hour traffic flow, symbolized as L_{10}; or (b) the equivalent sound level for the design hour, symbolized as L_{eq}. The day-night average sound level may be estimated from the design hour L_{10} or L_{eq} values by the following relationships, provided heavy trucks do not exceed 10 percent of the total traffic flow in vehicles per 24 hours and the traffic flow between 10 p.m. and 7 a.m. does not exceed 15 percent of the average daily traffic flow in vehicles per 24 hours:

$DNL \approx L_{10}$ (design hour)—3 decibels
$DNL \approx L_{eq}$ (design hour) decibels

Where the auto/truck mix and time of day relationships as stated in this Section do not exist, the HUD Noise Assessment Guidelines or other noise analysis shall be used.

(3) *Sites in the vicinity of installations producing loud impulsive sounds.* Certain Department of Defense installations produce loud impulsive sounds from artillery firing and bombing practice ranges. Noise analyses for these facilities sometimes encompass sites that may be subject to the requirements of this standard. Where such analyses are available they may be used on an interim basis to establish the acceptability of sites under this standard.

The Department of Defense uses day-night average sound level based on C-weighted sound level, symbolized L_{Cdn}, for the analysis of loud impulsive sounds. Where such analyses are provided, the 8 decibel addition specified in 51.103(b), is not required, and the same numerical values of day-night average sound level used on an interim basis to determine site suitability for non-impulsive sounds apply to the L_{Cdn}.

(4) *Use of areawide acoustical data.* HUD encourages the preparation and use of areawide acoustical information, such as noise contours for airports. Where such new or revised contours become available for airports (civil or military) and military installations they shall first be referred to the Regional Office (Environmental Clearance Officer) for review, evaluation and decision on appropriateness for use by HUD. The Regional Office shall submit revised contours to the Assistant Secretary of Community Planning and Development for review, evaluation and decision whenever the area affected is changed by 20 percent or more, or whenever it is determined that the new contours will have a significant effect on HUD programs, or whenever the contours are not provided in a methodology acceptable under § 51.106(a)(1) or in other cases where the Regional Office determines that Headquarters review is warranted. For other areawide acoustical data, review is required only where existing areawide data are being utilized and where such data have been changed to reflect changes in the measurement methodology or underlying noise source assumptions. Requests for determination on usage of new or revised areawide data shall include the following:

(i) Maps showing old, if applicable, and new noise contours, along with brief description of data source and methodology.

(ii) Impact on existing and prospective urbanized areas and on development activity.

(iii) Impact on HUD-assisted projects currently in processing.

(iv) Impact on future HUD program activity. Where a field office has determined that immediate approval of new areawide data is necessary and warranted in limited geographic areas, the request for approval should state the circumstances warranting such approval. Actions on proposed projects shall not be undertaken while new areawide noise data are being considered for HUD use except where the proposed location is affected in the same manner under both the old and new noise data.

(b) *Site assessments.* Compliance with the standards contained in § 51.103(c) shall, where necessary, be determined using noise assessment guidelines, handbooks, technical documents and procedures issued by the Department.

(c) *Variations in site noise levels.* In many instances the noise environment will vary across a site, with portions of the site being in an Acceptable noise environment and other portions in a Normally Unacceptable noise environment. The standards in § 51.103(c) shall apply to the portions of a building or buildings used for residential purposes and for ancillary noise sensitive open spaces.

(d) *Noise measurements.* Where noise assessments result in a finding that the site is borderline or questionable, or is controversial, noise measurements may be performed. Where it is determined that noise measurements are required, such measurements will be conducted in accordance with methods and measurement criteria established by the Department. Locations for noise measurements will depend on the location of noise sensitive uses that are nearest to the predominant noise source (see § 51.103(c)).

(e) *Projections of noise exposure.* In addition to assessing existing exposure, future conditions should be projected. To the extent possible, noise exposure shall be projected to be representative of conditions that are expected to exist at a time at least 10 years beyond the date of the project or action under review.

(f) *Reduction of site noise by use of berms and/or barriers.* If it is determined by adequate analysis that a berm and/or barrier will reduce noise at a housing site, and if the barrier is existing or there are assurances that it will be in place prior to occupancy, the environmental noise analysis for the site may reflect the benefits afforded by the berm and/or barrier.

In the environmental review process under § 51.104(b), the location height and design of the berm and/or barrier shall be evaluated to determine its effectiveness, and impact on design and aesthetic quality, circulation and other environmental factors.

Appendix—definition of acoustical quantities

1. *Sound Level.* The quantity in decibels measured with an instrument satisfying requirements of American National Standard Specification for Type 1 Sound Level Meters S1.4–1971. Fast time-averaging and A-frequency weighting are to be used, unless others are specified. The sound level meter with the A-weighting is progressively less sensitive to sounds of frequency below 1,000 hertz (cycles per second), somewhat as is the ear. With fast time averaging the sound level meter responds particularly to recent sounds almost as quickly as does the ear in judging the loudness of a sound.

2. *Average Sound Level.* Average sound level, in decibels, is the level of the mean-square A-weighted sound pressure during the stated time period, with reference to the square of the standard reference sound pressure of 20 micropascals.

Day-night average sound level, abbreviated as DNL, and symbolized mathematically as L_{dn} is defined as:

$$L_{dn} = 10 \log_{10} \left[\frac{1}{86400} \left(\int_{0000}^{0700} 10^{[L_A(t)+10]/10} \, dt + \int_{0700}^{2200} 10^{L_A(t)/10} \, dt + \int_{2200}^{2400} 10^{[L_A(t)+10]/10} \, dt \right) \right]$$

Time t is in seconds, so the limits shown in hours and minutes are actually interpreted in seconds. $L_A(t)$ is the time varying value of A-weighted sound level, the quantity in decibels measured by an instrument satisfying requirements of American National Standard Specification for Type 1 Sound Level Meters S1.4–1971.

3. *Loud Impulsive Sounds.* When loud impulsive sounds such as sonic booms or explosions are anticipated contributors to the noise environment at a site, the contribution to day-night average sound level produced by the loud impulsive sounds shall have 8 decibels added to it in assessing the acceptability of a site.

A loud impulsive sound is defined for the purpose of this regulation as one for which:

(i) The sound is definable as a discrete event wherein the sound level increases to a maximum and then decreases in a total time interval of approximately one second or less to the ambient background level that exists without the sound; and

(ii) The maximum sound level (obtained with slow averaging time and A-weighting of a Type 1 sound level meter whose characteristics comply with ANSI S1.4–1971) exceeds the sound level prior to the onset of the event by at least 6 decibels; and

(iii) The maximum sound level obtained with fast averaging time of a sound level meter exceeds the maximum value obtained with slow averaging time by at least 4 decibels.

Issued at Washington, D.C., on July 5, 1979.

Patricia Roberts Harris,

Secretary of Housing and Urban Development.

[FR Doc. 79-21481 Filed 7-11-79; 8:45 am]

BILLING CODE 4210-01-M

APPENDIX D

TRAFFIC MODEL

1. FHWA MODEL

TECHNICAL REPORT STANDARD TITLE PAGE

Report No. HWA-RD-77-108	2. Government Accession No.	3. Recipient's Catalog No.
Title and Subtitle HWA HIGHWAY TRAFFIC NOISE PREDICTION MODEL		5. Report Date December 1978 6. Performing Organization Code 33F4602
Author s' . M. Barry and J. A. Reagan		8. Performing Organization Report No. FHWA-RD-77-108
Performing Organization Name and Address ederal Highway Administration)ffice of Research, Office of Environmental Policy /ashington, D.C. 20590		10. Work Unit No. 11. Contract or Grant No. Staff Study
Sponsoring Agency Name and Address J.S. Department of Transportation ederal Highway Administration)ffice of Research, Office of Environmental Policy /ashington, D.C. 20590		13. Type of Report and Period Covered Final Report June 1977-December 1978 14. Sponsoring Agency Code

Supplementary Notes

Abstract

This report presents the FHWA method for predicting noise generated by constant speed highway traffic. The report is intended to be a users' manual as well as a reference document detailing the development, use, and limitations of the prediction method. In the main body of the report, the prediction procedure is presented in a step-by-step fashion and includes numerous example problems designed to highlight important concepts and features. For those interested in the theoretical development of the model, an extremely detailed derivation is presented in the appendices. The basis of the model is the equivalent sound level, L_{eq}, although an adjustment for conversion to L_{10} is provided. The method incorporates three classes of vehicles--automobiles, medium trucks, and heavy trucks. Adjustments for absorptive ground covers and finite length barriers are also included. Certain special topics such as nonuniform highway sites and determination of equivalent day-night levels, L_{dn}, are also included.

17. Key Words Traffic Noise, Traffic Noise Prediction, Traffic Noise Abatement		18. Distribution Statement This document is available to the public through: National Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 272	22. Price

Form DOT F 1700.7 (8-69)

THE FHWA HIGHWAY TRAFFIC NOISE PREDICTION MODEL

1.0 INTRODUCTION

The FHWA Highway Traffic Noise Prediction Model (hereafter referred to as the FHWA model), like several other prediction models, arrives at a predicted noise level through a series of adjustments to a reference sound level. In the FHWA model, the reference level is the energy mean emission level. Adjustments are then made to the reference energy mean emission level to account for traffic flows, for varying distances from the roadway, for finite length roadways, and for shielding. All of these variables are related by the following equation:

$$\begin{aligned} L_{eq}(h)_i = {} & (\overline{L_o})_{E_i} && \text{reference energy mean emission level} \\ & +10\log\left(\frac{N_i \pi D_o}{S_i T}\right) && \text{traffic flow adjustment} \\ & +10\log\left(\frac{D_o}{D}\right)^{1+\alpha} && \text{distance adjustment} \\ & +10\log\left(\frac{\psi_\alpha(\phi_1,\phi_2)}{\pi}\right) && \text{finite roadway adjustment} \\ & +\Delta_s && \text{shielding adjustment} \end{aligned} \qquad (1)$$

where

$L_{eq}(h)_i$	is the hourly equivalent sound level of the ith class of vehicles.
$(\overline{L_o})_{E_i}$	is the reference energy mean emission level of the ith class of vehicles.
N_i	is the number of vehicles in the ith class passing a specified point during some specified time period (1 hour).
D	is the perpendicular distance, in metres, from the centerline of the traffic lane to the observer.
D_o	is the reference distance at which the emission levels are measured. In the FHWA model, D_o is 15 metres. D_o is a special case of D.
S_i	is the average speed of the ith class of vehicles and is measured in kilometres per hour (km/h).
T	is the time period over which the equivalent sound level is computed (1 hour).
α	is a site parameter whose values depend upon site conditions.
ψ	is a symbol representing a function used for segment adjustments, i.e., an adjustment for finite length roadways.
Δ_s	is the attenuation, in dB, provided by some type of shielding such as barriers, rows of houses, densely wooded areas, etc.

The first two lines of Equation 1 predict the equivalent sound level generated by a flow of vehicles of a single class traveling at a constant speed on an effectively infinite, flat roadway at a reference distance of 15 metres. The last three lines of Equation (1) represent adjustments that deal with the site conditions between the observer and the roadway.

Once computation of the $L_{eq}(h)_i$'s is complete, the total hourly equivalent sound level, $L_{eq}(h)$ can be determined. The $L_{eq}(h)$ is the sum of the acoustic contributions of the various classes of vehicles using the roadway. In the FHWA model, there are three classes of vehicles: automobiles (A), medium trucks (MT), and heavy trucks (HT). The three classes of vehicles will be defined in the next section. The total hourly equivalent sound level is computed as:

$$L_{eq}(h) = 10 \log \left(10^{\frac{L_{eq}(h)_A}{10}} + 10^{\frac{L_{eq}(h)_{MT}}{10}} + 10^{\frac{L_{eq}(h)_{HT}}{10}} \right) . \qquad (2)$$

When the hourly sound level exceeded 10% of the time, $L_{10}(h)$, is desired, an adjustment is used to convert the $L_{eq}(h)_i$ to $L_{10}(h)_i$. The total $L_{10}(h)$ is also computed by logarithmically summing the contribution from each class:

$$L_{10}(h) = 10 \log \left(10^{\frac{L_{10}(h)_A}{10}} + 10^{\frac{L_{10}(h)_{MT}}{10}} + 10^{\frac{L_{10}(h)_{HT}}{10}} \right) . \qquad (3)$$

A complete discussion of the mathematical development of this model can be found in Appendices A and B.

Figure 1 is a flow diagram that shows the computational sequence followed in the FHWA manual method in arriving at a predicted sound level.

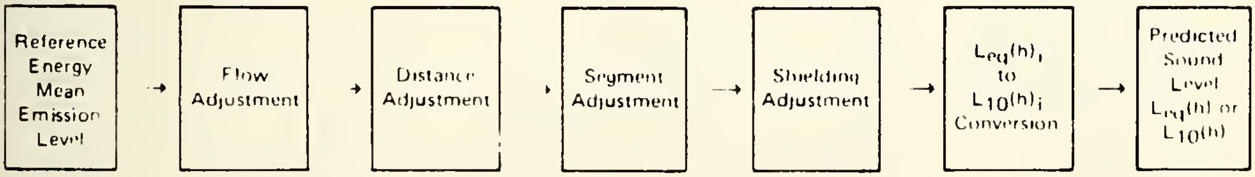

Reference Energy Mean Emission Level
Flow Adjustment
Distance Adjustment
Segment Adjustment
Shielding Adjustment
Leq(h)i to L10(h)i Conversion
Predicted Sound Level Leq(h) or L10(h)

Figure 1. Flow Diagram of the Computational Sequence Used in the FHWA Model

The computational procedure shown in Figure 1 is followed in Chapter 2 where each of the variables is discussed in detail. Each variable will be discussed separately and presented in graphical form for ease of calculations. Sample problems are included to illustrate the use of each chart or charts as they are developed. Finally, a summary is included at the end of each discussion to aid the user in following the computational sequence shown in Figure 1.

Chapter 3 examines equivalent lane distances with and without barriers present at the sites. Chapter 4 presents some nomographs which can be used to quickly estimate traffic noise levels. Chapter 4 also deals with the development of a computer program for a handheld calculator. Chapter 5 briefly discusses the accuracy of the FHWA model for those situations where D is equal to or greater than 15 metres. Chapter 6 discusses noise prediction when the observer is close to the highway (D is less than 15 metres), Chapter 7 presents some problems involving multilane highways.

2.0 FHWA MODEL — MANUAL METHOD ($D \geqslant 15$ Metres)

a. Introduction

As discussed in Chapter 1, the FHWA model arrives at a predicted sound level through a series of adjustments to the reference energy mean emission level. The actual value of these adjustments depends on input data concerning traffic characteristics, topography, and roadway characteristics. In the FHWA manual method presented in this chapter, these adjustments are read from figures and tables. Thus, the procedure used in arriving at a predicted noise level using the manual method developed for the FHWA model is very similar to the manual method used in the NCHRP 117/144 model. The figures have been changed, and the basic model is drastically different, but the computational procedure is very similar.

Table 1 has been prepared to assist the user in keeping track of these adjustments. The notation in Table 1 is slightly different from that used in Equation (1). The reason for this will become apparent as each term in Equation 1 is discussed.

NAME

DATE

PROJECT DESCRIPTION

1	LANE NO ROAD SEGMENT																			
2	VEHICLE CLAS		A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT	A	MT	HT
3	N(vph)																			
4	S(km/h)																			
5	D(m)																			
6	ϕ_1 (degrees)	Fig 5																		
7	ϕ_2 (degrees)	Fig 5																		
8	$(\overline{L_0})_{E_i}$ (dBA)	Fig 2																		
9	10 LOG ($N_i D_0/S_i$) (dB)	Fig 3																		
10a	10 LOG (D_0/D) (dBA)	Fig 4																		
10b	15 LOG (D_0/D) (dBA)	Fig 4																		
11a	10 LOG ($\psi_0(\phi_1, \phi_2)/\pi$) (dBA)	Fig 6																		
11b	10 LOG ($\psi_{1/2}(\phi_1, \phi_2)/\pi$) (dBA)	Fig 7																		
12	ϕ_L (degrees)	Fig 10																		
13	ϕ_R (degrees)	Fig 10																		
14	δ_0 (metres)	Fig 9																		
15	N_0	Eq 18																		
16	Δ_B (dBA)	Appendix B																		
17	CONSTANT (dB)		-25	25	-25	-25	-25	-26	-26	-25	-25	-25	-26	-25	-25	-25	-25	-25	-25	-25
18	$L_{eq}(h)$ (dBA)																			
19	$L_{eq}(h)$ (dBA)																			
20	Δ_s (dBA)	Fig 8																		
21	$L_{eq}(h)$ (dBA)																			
22	$L_{eq}(h)$ (dBA)																			
23	ND/S (m/km)																			
24	($L_{10} - L_{eq}$) (dB)	Fig 15																		
25	$L_{10}(h)_i$ (dBA)																			
26	$L_{10}(h)$ (dBA)																			
27	$L_{10}(h)$ (dBA)																			

Table 1. Noise Prediction Worksheet

b. Reference Energy Mean Emission Level

Figure 1 indicated that the first step in the prediction procedure was to determine the reference energy mean emission level for each class of vehicles that uses the highway. This requires a knowledge of the emission levels of the individual vehicles traveling on the highway. The emission level, L_o, is defined as the *A*-weighted peak pass-by noise level generated by a vehicle as measured by a microphone at a specified location. In the FHWA model, the microphone is located on a line perpendicular to the centerline of the traffic lane at a distance of 15 metres from the centerline of the traffic lane. Microphone height is 1.5 metres. The intervening terrain between the traffic lane and the microphone should be flat and free of reflective surfaces. When the measurement is made, the vehicles should be operating on a straight, flat roadway under constant speed conditions and in cruise mode in the near lane. Care must be taken to insure that the measured emission levels are free from extraneous sounds. Detailed procedures for measuring noise emission levels are given in a manual under preparation by FHWA [11, 12].

Unfortunately, the vehicles that use the highways do not have identical emission levels. Emission levels depend on several factors, such as the type of vehicle, engine size, speed, tire type, etc. Since it is not practical to determine the emission levels for all vehicles in each class, it becomes necessary to measure the emission levels of a large number of different types of vehicles at various speeds and statistically determine the reference energy mean emission levels. This is usually done on a computer using standard curve fitting and statistical techniques. This type of analysis has been done [2] using the data acquired in the Four-State Noise Inventory [3]. Based on this analysis and other data [2-6], vehicles can be placed in three acoustic source groups.

(1) *Automobiles (A)* — all vehicles with two axles and four wheels designed primarily for transportation of nine or fewer passengers (automobiles), or transportation of cargo (light trucks). Generally, the gross vehicle weight is less than 4,500 kilograms.

(2) *Medium trucks (MT)* — all vehicles having two axles and six wheels designed for the transportation of cargo. Generally, the gross vehicle weight is greater than 4,500 kilograms but less than 12,000 kilograms.

(3) *Heavy trucks (HT)* — all vehicles having three or more axles and designed for the transportation of cargo. Generally, the gross weight is greater than 12,000 kilograms.

The FHWA model uses the following *A* weighted national reference energy mean emission levels:

$$(\overline{L}_o)_{E_A} = 38.1 \log(S) - 2.4 \qquad (4)$$

$$(\overline{L}_o)_{E_{MT}} = 33.9 \log(S) + 16.4 \qquad (5)$$

$$(\overline{L}_o)_{E_{HT}} = 24.6 \log(S) + 38.5 \qquad (6)$$

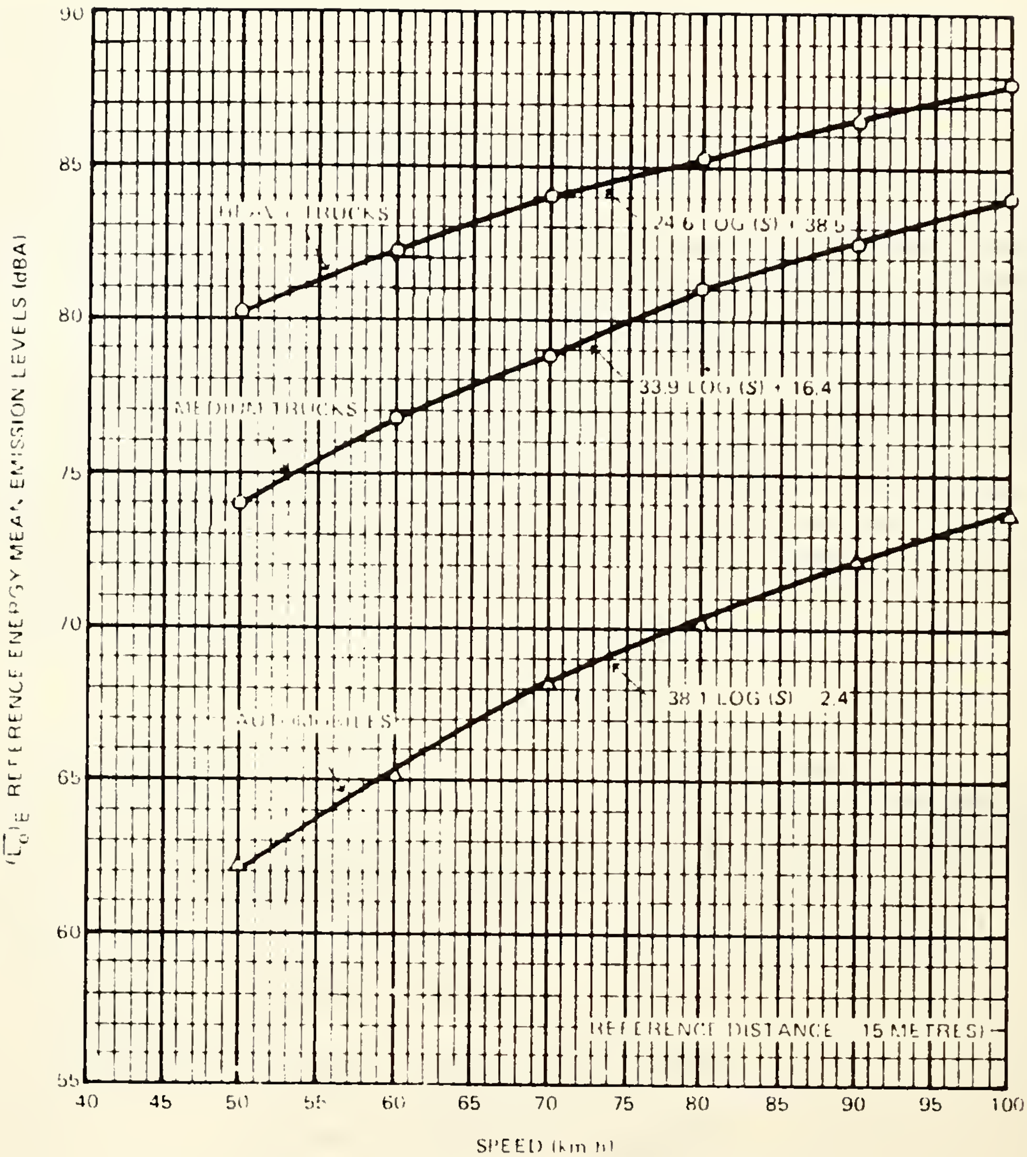
where S is the average vehicle speed of the vehicle class in km/h.

Equation (4) is from FHWA Research Report No. FHWA-RD-77-19 [4]. Equations (5) and (6) are from FHWA Research Report FHWA-RD-78-64 [2].

The reference energy mean emission levels shown here are plotted in Figure 2. It is emphasized that the truck levels are national averages based on the truck data acquired in the Four-State Noise Inventory [3].

The Four-State Noise Inventory indicated that there are regional trends in vehicle types. For example, the majority of large trucks in Florida had four axles. Consequently, the reference energy mean emission level given in Equation (6) may result in overprediction of the noise levels on Florida highways. Users of this manual may develop their own reference levels using the FHWA prescribed measurement procedures [12].

The three vehicle categories discussed here are identical to those reported in NCHRP Report 173. Although the vehicle categories are the same, the emission levels are not. The reason for this is unclear. One possible explanation is that the measurements were made at different times. The



SOURCE: "Statistical Analysis of FHWA Traffic Noise Data," FHWA-RD-78-64

△ SOURCE: "Update of TSC Highway Traffic Noise Prediction Code (1974)," FHWA-RD-77-19

Figure 2. National Reference Energy Mean Emission Levels as a Function of Speed

vehicle measurements shown in NCHRP Report 173 were made before 1974. The vehicle measurements in the Four-State Noise Inventory were made in 1975.

One interesting point is the distinction made in NCHRP Report 173 between emission levels and source levels. NCHRP Report 173 reported a 4 dB error between measured sound levels and predicted sound levels. This 4 dB error was subtracted from the emission levels, and these quantities were defined as source levels. The source levels given in NCHRP Report 173 and the emission levels given here have approximately the same numerical values for the emission levels of the automobiles and medium trucks. The levels for the heavy trucks are approximately the same at high speed but not at low speed. This is because the source level for heavy trucks in NCHRP 173 is independent of speed.

c. Traffic Flow Adjustments to the Reference Levels

Figure 2 is used to determine the reference energy mean emission level for a single vehicle representative of a particular class. This value must then be adjusted for traffic flows by use of the term

$$10 \log (N_i \pi D_o / T S_i) \, . \tag{7}$$

This expression is valid for any consistent set of units. The units used by highways engineers are not consistent. N_i is the number of vehicles in the ith class passing a given point over a 1-hour period; D_o is equal to 15 metres; T is equal to 1-hour; and S_i is measured in kilometres per hour. Consequently, for ease of use, the expression $10 \log (N_i \pi D_o / T S_i)$ is simplified to $10 \log (N_i D_o / S_i) - 25$ (Note: $-25 = 10 \log \pi - 10 \log 1000$). Consequently, the adjustment for traffic flow reduces to

$$10 \log \left(\frac{N_i D_o}{S_i} \right) - 25 \, . \tag{8}$$

Note that in Table 1, Line 17, the −25 is treated as an equation constant. The units are the same as defined above.

D_o is kept in Equation (8) for two reasons:

(1) It emphasizes that the emission levels used in the FHWA model were measured at a distance of 15 metres.

(2) It serves as an alert mechanism. When D is less than 15 metres, noise predictions must be made in accordance with the procedures in Chapter 6.

Since D_o is a constant in the term $10 \log (N_i D_o / S_i)$, the traffic flow adjustment factor varies as the logarithm of N_i / S_i. If N_i is held constant, the adjustment factor decreases with increasing speed at the rate of 3 dBA per doubling of speed. If S_i is held constant and the volume increases, the adjustment factor increases by 3 dBA for each doubling of volume.

The name given to the adjustment in this section – the traffic flow adjustment – is somewhat of a misnomer because Equation (7) has one other important function. Recall that T is the time period over which the equivalent sound level is computed. By making T equal to one hour, the reference energy mean emission level (a peak value) is converted to an hourly equivalent sound level.

The adjustment for traffic flows can be read directly from Figure 3.

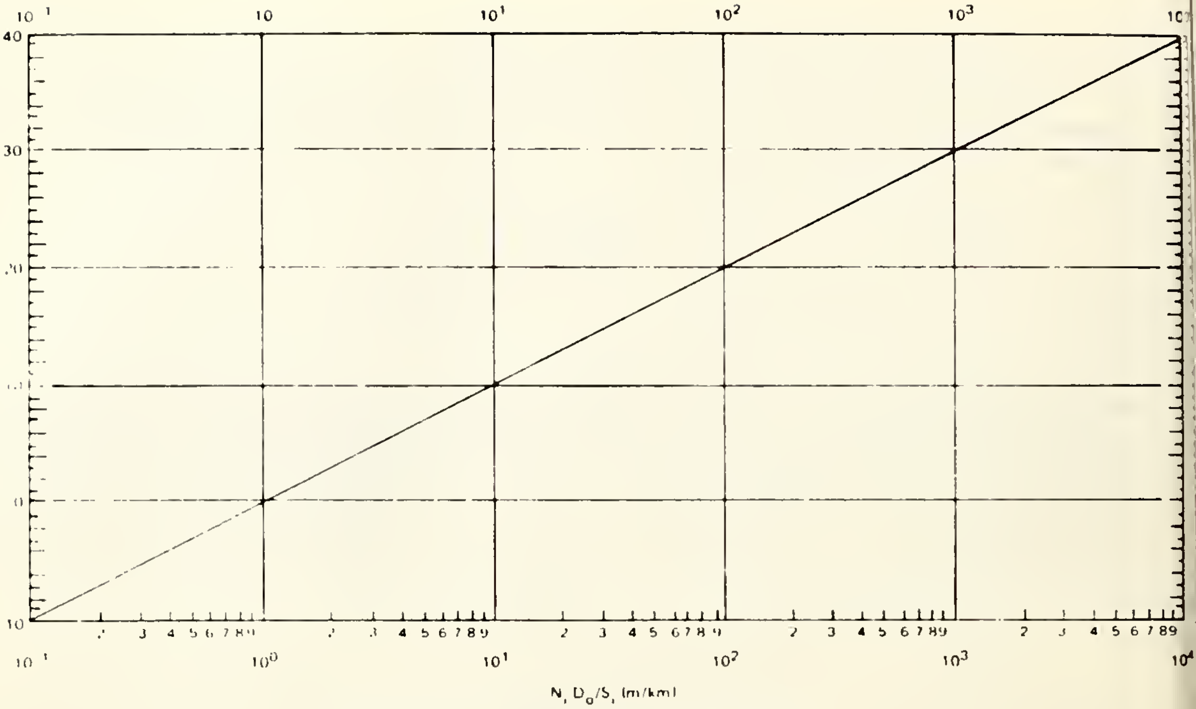


Figure 3. Adjustment for Real Traffic Flows

d. Distance Adjustment to the Reference Levels

The reference energy mean emission levels are equivalent sound levels based on single vehicle, peak pass-by noise level measurements made at a distance of 15 metres from the roadway. Predicting the noise level at distances greater than 15 metres requires that the reference energy mean emission levels be adjusted for the new distances. The distances adjustment is generally referred to as the drop-off rate and is expressed in terms of decibels per doubling of distance (dB/DD). Since the reference energy mean emission levels are equivalent sound levels, the distance adjustment factor can be expressed as

$$10 \log \left(\frac{D_o}{D}\right)^{1+\alpha} \quad . \qquad (9)$$

where

D is the perpendicular distance between the centerline of the travel lane and the observer.

D_o is the reference distance at which the reference energy mean emission level was measured and equals 15 metres. Note that D_o is a special case of D.

α is a site parameter whose value depends upon site conditions.

Theoretically, it can be shown that when the ground between the roadway and observer is acoustically hard, the site is reflective ($\alpha = 0$). Consequently, the distance adjustment factor reduces to

$$10 \log \left(\frac{D_o}{D}\right) \qquad (10)$$

and the drop-off rate is 3 dB per doubling of distance (3 dBA/DD). Values close to this theoretical value have been measured in the field [3].

Field studies [3,5] have also shown that when the intervening ground is acoustically soft the site is absorptive ($\alpha \approx 1/2$). In this situation, the distance adjustment factor reduces to

$$15 \log \left(\frac{D_o}{D} \right) \tag{11}$$

and the drop-off rate is 4.5 dBA per doubling of distance (4.5 dBA/DD). In this case, it appears that the 4.5 dBA/DD attenuation is made up of two components—the 3.0 dBA/DD due to geometric spreading and an excess attenuation of 1.5 dBA/DD due to ground effects.

It is important that the users of this manual understand what the values given by Equations 10 and 11 represent. Consider the situation where two sound level meters (SLM's) are located adjacent to a highway. One SLM is located at distance D and the other SLM is located at distance $2D$. As a vehicle approaches and passes the SLM's, the noise level increases up to a peak level and then decreases. If simultaneous readings of the peak levels were recorded, the difference in levels between the two SLM's would be 6 or 7.5 dBA (6.0 dBA due to divergence and 1.5 dBA due to excess attenuation if the site is absorptive). However, if comparisons were made between the equivalent sound levels computed from the pass-by envelopes, the difference in the equivalent sound levels between the SLM's would range from 3 to 4.5 dBA. Equations (10) and (11) are based on equivalent sound levels.

In the FHWA model, the user must decide the proper drop-off rate to use. Table 2 has been prepared to help the user make this decision.

As shown earlier, the 3 dBA/DD takes the form of $10 (\log D_o/D)$ and the 4.5 dBA/DD takes the form of $15 \log (D_o/D)$. These functions are shown graphically in Figure 4.

Table 2. Criteria for Selection of Drop-Off Rate Per Doubling of Distance

Situation	Drop-Off Rate
1. All situations in which the source or the receiver are located 3 metres above the ground or whenever the line-of-sight* averages more than 3 metres above the ground.	3 dBA ($\alpha = 0$)
2. All situations involving propagation over the top of a barrier 3 metres or more in height.	3 dBA ($\alpha = 0$)
3. Where the height of the line-of-sight is less than 3 metres and	
(a) There is a clear (unobstructed) view of the highway, the ground is hard and there are no intervening structures.	3 dBA ($\alpha = 0$)
(b) The view of the roadway is interrupted by isolated buildings, clumps of bushes, scattered trees, or the intervening ground is soft or covered with vegetation.	4.5 dBA ($\alpha = 1/2$)

*The line-of-sight (L/S) is a direct line between the noise source and the observer.

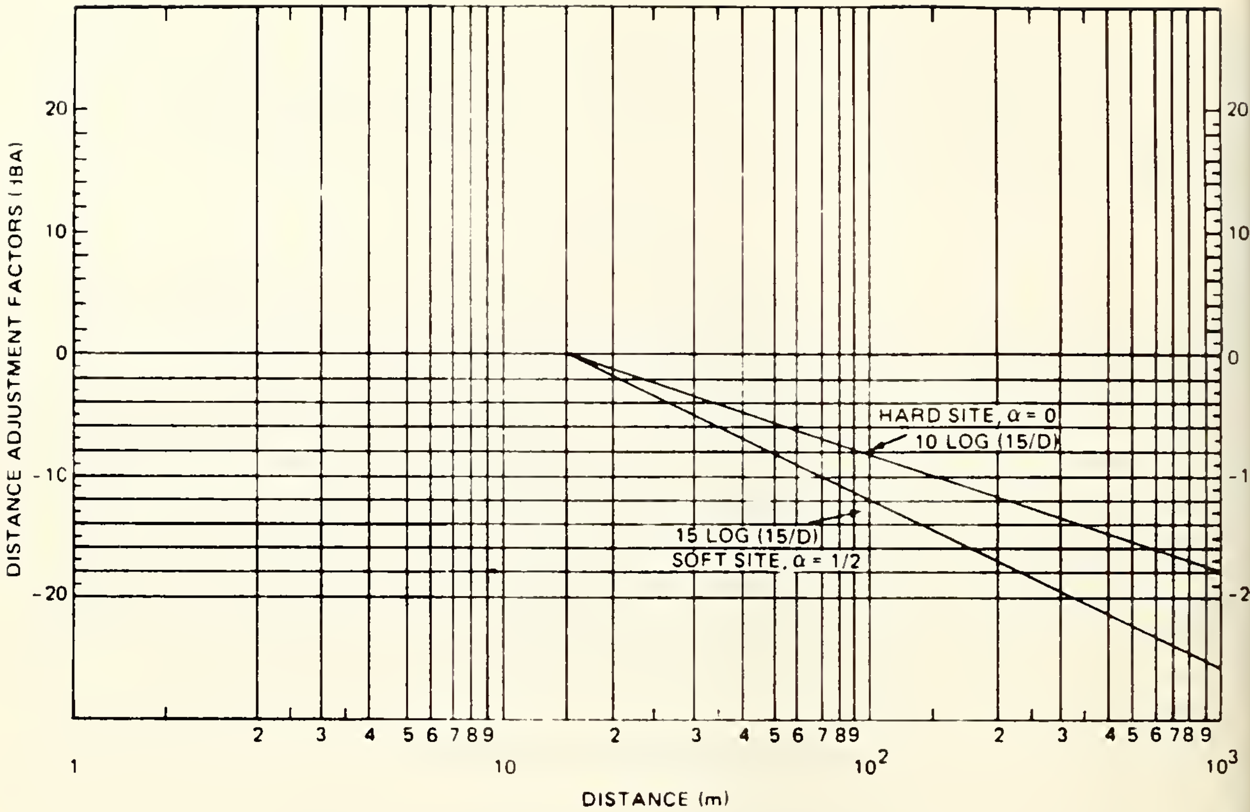


Figure 4. Adjustments for Distances Other than 15 Metres

e. Finite Length Roadway Adjustments to the Reference Levels

Up to this point, it has been assumed that the roadway is infinitely long in both directions in relation to the observer. In many cases, this is not true, and it becomes necessary to adjust the reference level to account only for the energy contribution of the roadway that is visible to the observer. Additionally, it is often necessary to separate a roadway into sections to account for changes in topography, traffic flows, shielding, etc. In these situations, the roadway will be divided into segments of finite length [6]. The finite length roadway adjustment depends on the orientation of these highway segments relative to the observer and on ground effects.

1. *Orientation of Highway Segement*

The following procedure will be used to determine the angular relationship between the roadway segment and an observer facing the highway segment. (Refer to Figure 5)

Step 1. Draw a perpendicular line from the roadway, or the roadway extension to the observer. All angles are measured from this perpendicular.

Step 2. Draw a line from the observer to the left most end of the highway segment. The angle measured from the perpendicular drawn in Step 1 to the line connecting the observer and the left most end of the roadway segment is ϕ_1. If ϕ_1 is measured to the left of the perpendicular it is negative. If ϕ_1 is measured to the right of the **perpendicular** it is positive.

Step 3. Draw a line from the observer to the right most end of the highway segment. The angle measured from the perpendicular drawn in Step 1 to the line connecting the observer and the right most end of the highway segment is ϕ_2. If ϕ_2 is measured to the left of the perpendicular, it is negative, if ϕ_2 is measured to the right of the perpendicular it is positive.

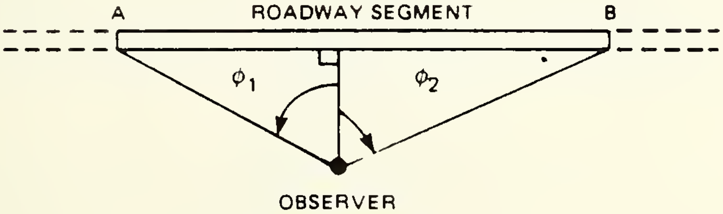
Step 4. Check the angles ϕ_1 and ϕ_2 by use of the equation

$$\Delta\phi = \phi_2 - \phi_1 \tag{12}$$

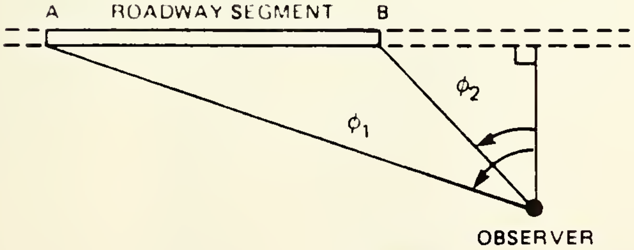
where

ϕ_1 and ϕ_2 are the angles in degrees identified in Steps 1-3 above.

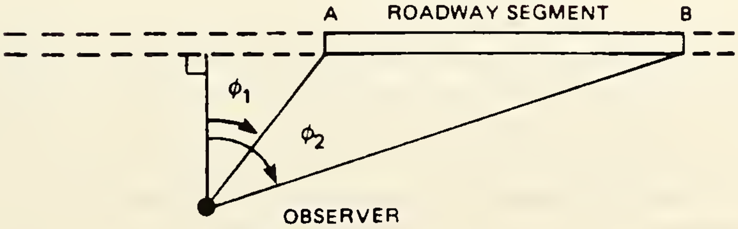
In all cases $\Delta\phi$ will be positive and will be numerically equal to the included angle subtended by the roadway relative to the receiver



(1) CASE A



(2) CASE B



(3) CASE C

Figure 5. Angle Identification of Roadway Segments

2. *Ground Effects*

The problem of finite length roadways is complicated by the fact that ground effects must be taken into account. In the section on distance adjustments, it was indicated that the drop-off rate was a function of the height of the line-of-sight and the nature of the terrain between the observer and the roadway. The finite length roadway adjustment is also affected by these factors. Consequently, the finite length roadway adjustment factor takes the form of

$$10 \log \left(\frac{\psi_{\alpha}(\phi_1, \phi_2)}{\pi} \right) \qquad (13$$

where

$\psi_{\alpha}(\phi_1, \phi_2)$ is a factor that takes finite length roadways into account.

ϕ_1, ϕ_2 are the angles defined in Figure 5.

α is the site parameter.

When $\alpha = 0$, the site is reflective (i.e., the drop-off rate is 3 dBA/DD) and the term $10 \log(\psi_0(\phi_1, \phi_2)/\pi)$ reduces to $10 \log(\Delta\phi/\pi)$ where $\Delta\phi$ is defined in Equation (12).

This implies that roadways subtending equal angles contribute equal energy regardless of their position relative to the observer when the site is reflective. The function (Equation (13) is illustrated graphically in Figure 6.

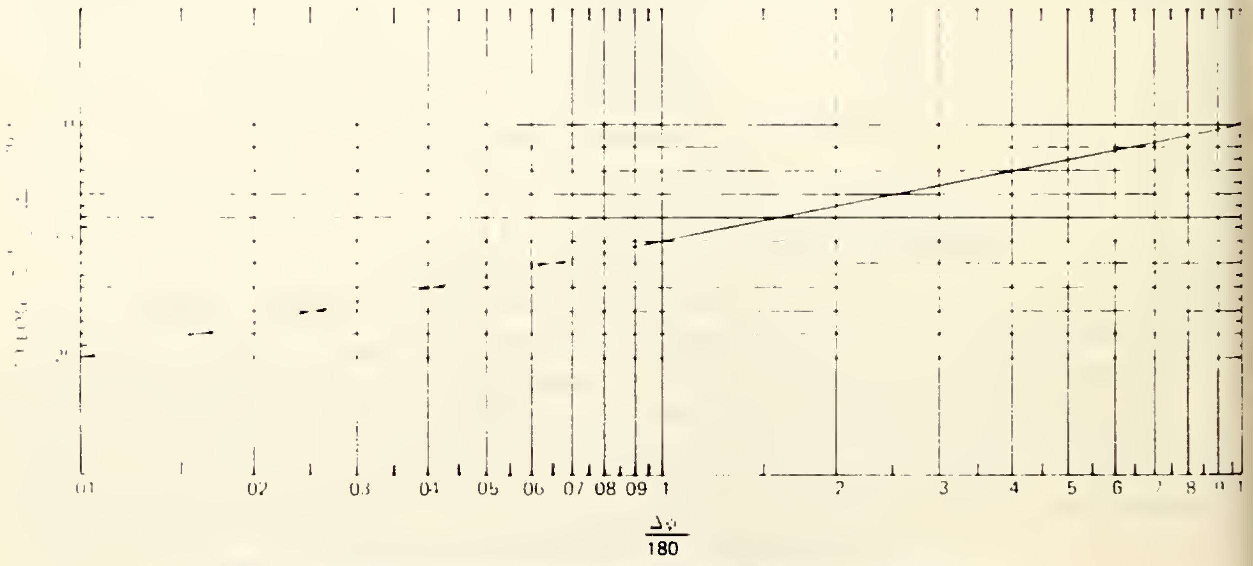


Figure 6. Adjustment Factor for Finite Length Roadways for Hard Sites ($\alpha = 0$)

When $\alpha = 1/2$, the site is absorptive (i.e., the drop-off rate is 4.5 dBA/DD). At absorbing sites, the correction $10 \log(\psi_{1/2}(\phi_1, \phi_2)/\pi)$ reduces to an integration of $\sqrt{\cos \phi}$ over the angular limits of the roadway. This integration has been performed for $\alpha = 1/2$ and the results plotted as a family of curves shown in Figure 7. One extremely important *consequence of absorption* at a highway site is that roadways subtending equal angles will not necessarily contribute equal energies. The amount of energy contributed will depend on the position of the observer relative to the roadway segment. Figure 7 also indicates that the adjustment for an infinitely long roadway is a −1.2 dBA. This results from the assumption that there are no differences in emission levels (measured at 15 metres) over hard and soft sites. (See Appendices A and C for further details.)

Although the distance adjustment and the finite length roadway adjustment were discussed separately, both values depend on the site parameter α. Under free field conditions (the observer has a unobstructed view of the highway or highway section), the same site parameter should be used to make both adjustments on the same highway or highway segment. Thus if $\alpha = 1/2$ is used for the distance adjustment, it should also be used for the finite length roadway adjustment.

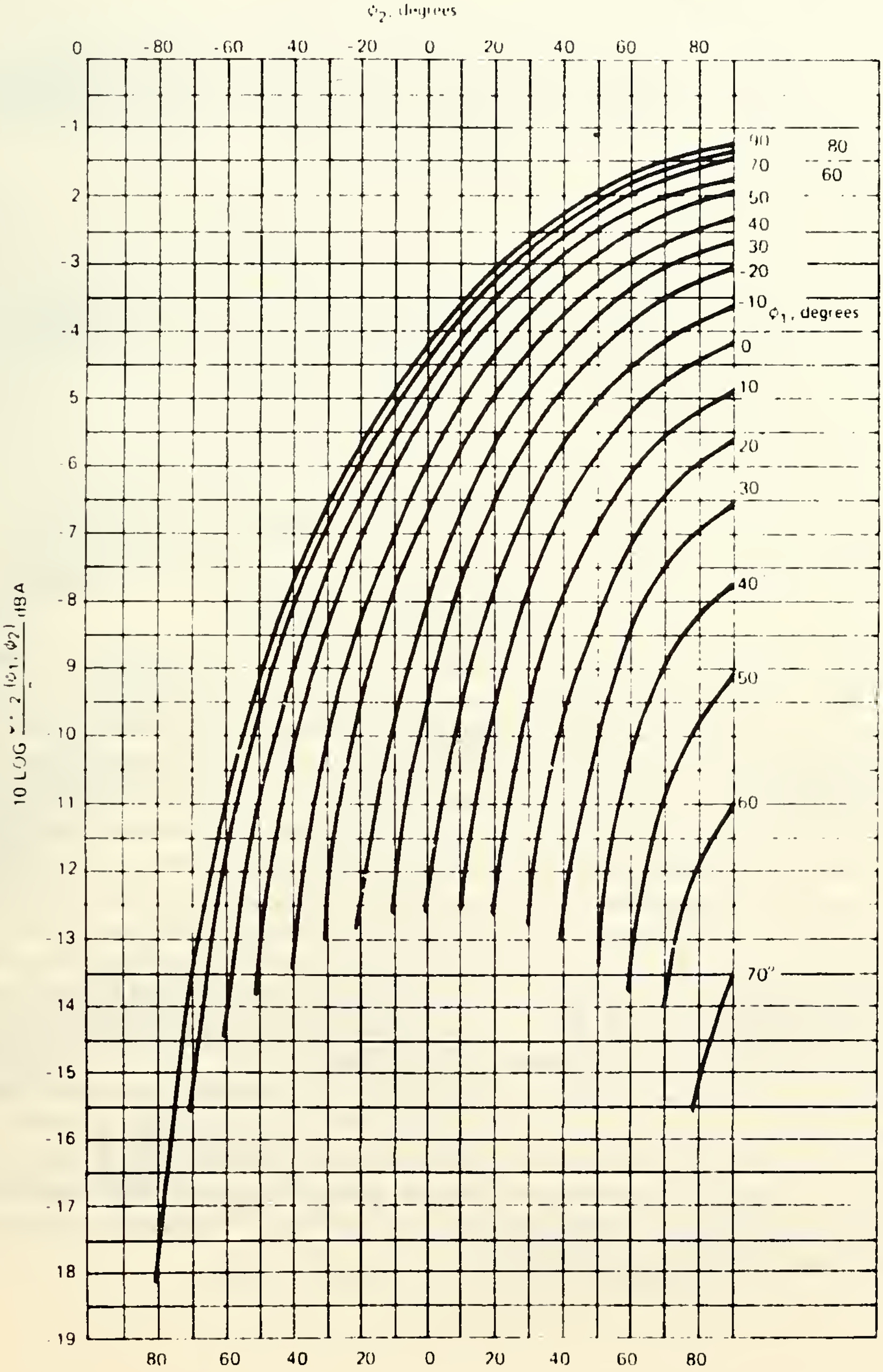


Figure 7. Adjustment Factor for Finite Length Roadways for Absorbing Sites ($\alpha = 1/2$)

f. Shielding Adjustments to the Reference Levels

So far it has been shown that, as a minimum, the equivalent sound levels generated by a stream of traffic decrease at the rate of 3 dBA/DD. This attenuation is accounted for explicitly in the FHWA model when the site parameter is zero ($\alpha = 0$). This phenomenon is illustrated in Figure 8(a).

It has also been discussed that in many situations ground effects can lead to an additional attenuation of up to 1.5 dBA/DD. This only occurs when both the source and receiver are close to the ground and the terrain between the observer and the roadway is relatively flat and soft [6,8]. As a result of this additional attenuation, the equivalent sound levels decrease at a rate of approximately 4.5 dBA/DD at soft sites. Excess attenuation is accounted for explicitly in the FHWA model when the site parameter is one-half ($\alpha = 1/2$). This is illustrated in Figure 8(b). Note that the attenuation rates shown in Figure 8(a) and Figure 8(b) are not additive the user can only choose one, based upon site conditions.

Attenuation due to temperature gradients, winds, and atmospheric absorption also occur but these phenomenon are ignored in the FHWA method. Attenuation due to wind and temperature gradients is ignored for two reasons (1) atmospheric conditions vary widely from hour to hour and from site to site and the (2) attenuation they provide is not permanent. Atmospheric absorption, caused by water vapor, is not important in highway work because of the long distances sound must travel before the attenuation from this mechanism becomes significant. Although atmospheric effects are not important in prediction, they can be very important when making measurements.

Attenuation due to shielding is also an important mechanism by which highway sound levels are lowered. Shielding occurs when the observer's view of a highway is obstructed or partially obstructed by an object or objects which significantly interfere with the propagation of the sound waves. Shielding can be provided by dense woods, rows of buildings, and/or barriers.

1. *Dense Woods and Rows of Buildings* [6,11]

Enough information is known about dense woods and rows of buildings to account for the attenuation they provide by simple rules of thumb. If the woods are very dense, i.e., there is no clear line of sight between the observer and the source, and if the height of the trees extends at least 5 metres above the line of sight, then 5 dBA attenuation is allowed if the woods have a depth of 30 metres. An additional 5 dBA may be obtained if the depth of the woods extends for another 30 metres. 10 dBA is the maximum attenuation dense woods can provide. This is illustrated in Figure 8(c).

The amount of attenuation provided by rows of buildings depends upon the actual length of the row occupied by the buildings. 3 dBA is provided by the first row when the buildings occupy 40 to 65 percent of the length of the row and 5 dBA when the buildings occupy 65 to 90 percent of the length of the row. No attenuation is allowed for rows of houses that occupy less than 40 percent of the length of the row. 1.5 dBA additional attenuation is provided by each successive row until a total attenuation of 10 dBA for all rows is obtained. This is the maximum attenuation that this mechanism provides. This is illustrated in Figure 8(d).

The excess attenuation provided by ground effects is assumed to end when the sound waves reach the dense woods or the first row of buildings. Thus the attenuation provided by dense woods and rows of buildings is only additive to the attenuation provided by geometric spreading (3 dBA/DD). In addition, the combined effects of dense woods and rows of buildings are only additive until a maximum of 10 dBA attenuation is achieved. Thereafter the effects of additional woods and rows of buildings is ignored [6].

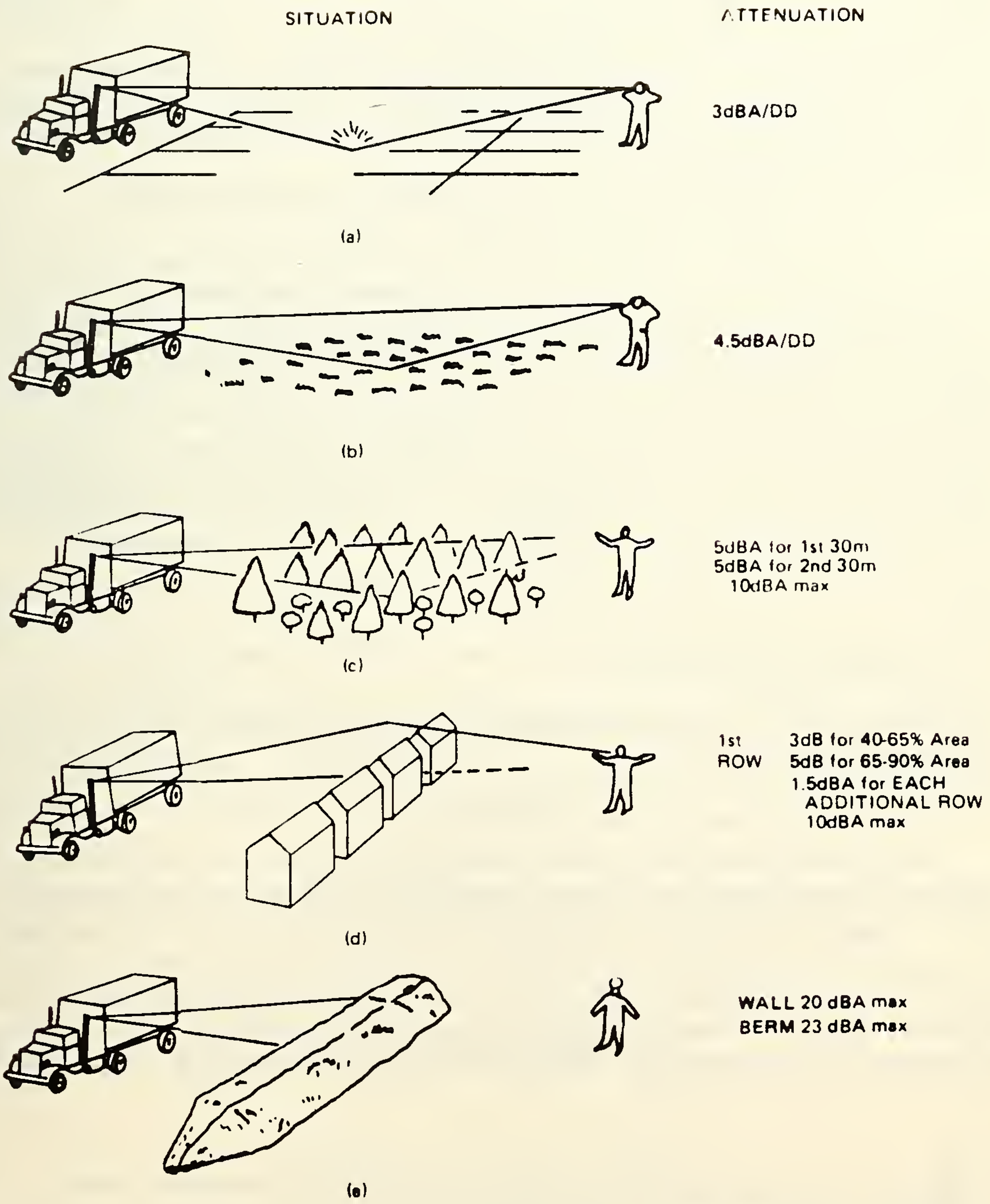


Figure 8. Attenuation of Highway Traffic Noise

2. *Barriers*

Barriers include such items as berms, walls, large buildings, hills, etc., that affect sound propagation by interrupting its propagation and creating an "acoustic shadow zone." The sound level is lower in the shadow zone than in the respective free field. This is illustrated in Figure 8(e). In recent years, the construction of noise barriers has become a fairly common method of abating highway traffic noise. Although this section only addresses manmade barriers constructed specifically for highway noise abatement, the principles are applicable to large buildings, hills, depressed sections, etc.

Barriers have been constructed of a variety of materials and in three basic shapes—earth berms, freestanding walls, and combinations berm-walls. A few of the early barriers did not provide the attenuation for which they were designed. Evaluation of these barriers has pointed out several crucial features of noise barriers [7-9]:

(1) The transmitted noise must be 10 dBA less than the diffracted noise.

(2) The barriers cannot have cracks in them.

(3) The barriers must be high enough to break the line-of-sight between the observer and source and long enough to prevent noise leaks around the ends.

These problems may now be satisfactorily addressed by engineers. Two additional considerations have recently emerged that must be addressed to ensure satisfactory barrier design [8]. It appears that the shape of the barrier affects the amount of attenuation. Recent data suggests that earth berms provide about 3 dBA more attenuation than freestanding walls. Although it is not clear at this time why this is true, it probably has something to do with absorption or edge effects. The second consideration requires the introduction of an expression familiar to acoustical engineers but alien to highway engineers –field insertion loss (I. L.). Field insertion loss is simply the difference in the noise levels at the same location before and after the barrier is constructed.

$$\text{Field Insertion Loss (I. L.)} = L\ (\text{Before}) - L\ (\text{After}) \qquad (14)$$

where

L represents $L_{eq}(h)$ or $L_{10}(h)$.

Thus three elements must be accounted for in barrier designs: barrier attenuation, barrier shape, and field insertion loss.

(a) *Barrier Attenuation and Barrier Shape*

The attenuation provided by a freestanding wall can be expressed as a function of the Fresnel number, the barrier shape, and the barrier length in the following form (see Appendix B),

$$\Delta_{B_i} = 10 \log \left[\frac{1}{\phi_R - \phi_L} \int_{\phi_L}^{\phi_R} 10^{\frac{-\Delta_i}{10}}\, d\phi \right] \qquad (15)$$

where

Δ_{B_i} is the attenuation provided by the barrier for the ith class of vehicles.

ϕ_R, ϕ_L are angles that **establish the relationship** (position) **between** the barrier and the observer.

$$\Delta_i = \begin{cases} 0 & N_i \leq -0.1916 - 0.0635\epsilon \\ 5(1+0.6\epsilon) + 20\log\dfrac{\sqrt{2\pi|N_o|_i\cos\phi}}{\tan\sqrt{2\pi|N_o|_i\cos\phi}} & (-0.1916 - 0.0635\epsilon) \leq N_i \leq 0 \\ 5(1+0.6\epsilon) + 20\log\dfrac{\sqrt{2\pi(N_o)_i\cos\phi}}{\tanh\sqrt{2\pi(N_o)_i\cos\phi}} & 0 \leq N_i \leq 5.03 \\ 20(1+0.15\epsilon) & N_i \geq 5.03 \end{cases}$$

where Δ_i is the point source attenuation for the *i*th class of vehicles.

$N_i = (N_o)_i \cos\phi$

ϵ is a barrier shape parameter, 0 for a freestanding wall and 1 for an earth berm.

N_o is the Fresnel number determined along the perpendicular line between the source and receiver.

N_{o_i} is the Fresnel number of the *i*th class of vehicles determined along the perpendicular line between the source and receiver.

Mathematically the Fresnel number, N_o, is defined as

$$N_o = 2\left(\frac{\delta_o}{\lambda}\right) \tag{16}$$

where

δ_o is the pathlength difference measured along the perpendicular line between the source and receiver.

λ is the wavelength of the sound radiated by the source.

The pathlength difference, δ_0, is the difference between a perpendicular ray traveling directly to the observer and a ray diffracted over the top of the barrier,

$$\delta_o = A_o + B_o - C_o \tag{17}$$

where the distances A_o, B_o, and C_o are the distances shown in Figure 9. Note that if the height of the noise source or the observer changes, the pathlength difference will also change.

Highway traffic noise is broadband, i.e., contains energy in the frequency bands throughout the audible range and the Fresnel number will vary according to the frequency chosen. However it has been shown that the attenuation of the *A*-weighted sound pressure level of a typical car is almost identical to the sound attenuation of the 550 Hertz band [10]. Based on this, it is generally assumed

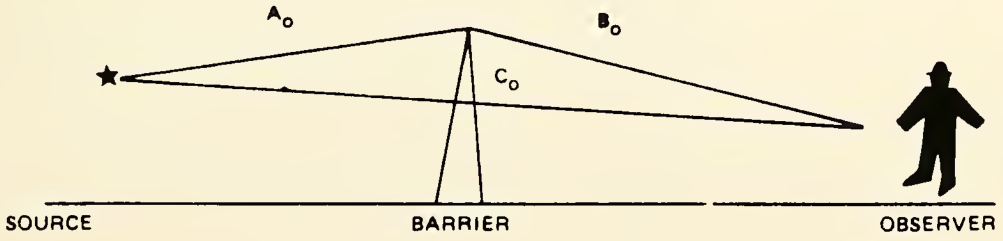


Figure 9. Pathlength Difference, δ_o

that the effective radiating frequency of highway traffic noise for all classes of vehicles is 550 Hz. Therefore, Equation (15) reduces to:

$$N_o = 2\left(\frac{\delta_o}{\lambda}\right) = 2\left(\frac{f\delta_o}{c}\right) = 2\left(\frac{550\delta_o}{343}\right) = 3.21(\delta_o) \text{ metres.} \qquad (18$$

For barrier calculations only, the vehicle noise sources are assumed to be located at the following positions:

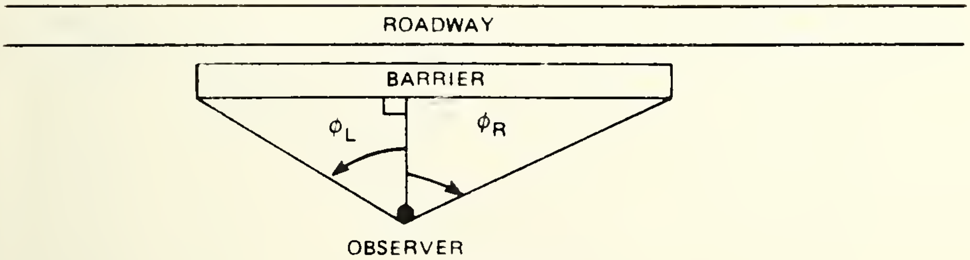
(1) Automobiles — 0 metres above the centerline of the lane.
(2) Medium Trucks — 0.7 metres above the centerline of the lane.
(3) Heavy Trucks — 2.44 metres above the centerline of the lane.

The above positions attempt to take into account and centralize the locations of the many individual sources contributing to the overall noise radiated by medium and heavy trucks, i.e., tire, engine, exhaust, etc.

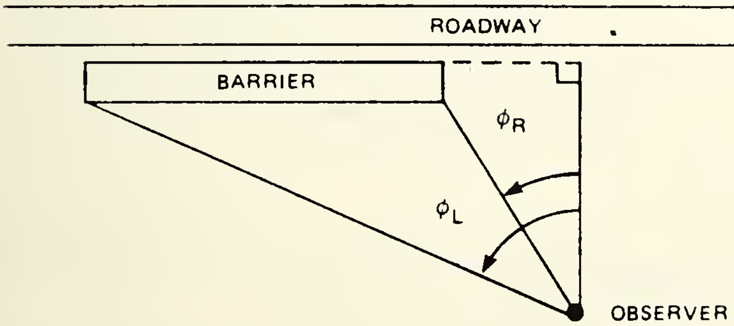
For barriers of finite length, the attenuation provided by a barrier depends on how much of the roadway is shielded from the observer. Thus, it is necessary to establish the angular relationship between the roadway and the observer and between the barrier and the observer. The angular relationship between the roadway and the observer was discussed in Section 2(e) and illustrated in Figure 5. The same procedure is used to establish the angular relationship between the barrier and the observer, except that the angles which establish the end points of the barrier are identified as ϕ_L and ϕ_R. This orientation assumes that the observer is facing the barrier. The angle measured from the perpendicular to the left most end of the barrier is ϕ_L. The angle measured from the perpenducular to the right most end of the barrier is ϕ_R. Angles measured to the left of the perpendicular are negative and angles measured to the right of the perpendicular are positive. Only three cases are possible and they are shown in Figure 10. The advantage of this procedure is that the observer can now be located at any point and the attenuation provided by the barrier can be computed.

With knowledge of N_o, ϕ_L, ϕ_R the integral in Equation (15) can be solved. This integral has been numerically integrated for a range of values of $N_o = -0.2$ to $N_o = 100$, and is presented in ten degree increments in Appendix B. The barrier attenuation values given in these tables are for free-standing walls. When using the tables to determine the attenuation due to earth berms, add 3 dBA to the values shown in the tables [8].

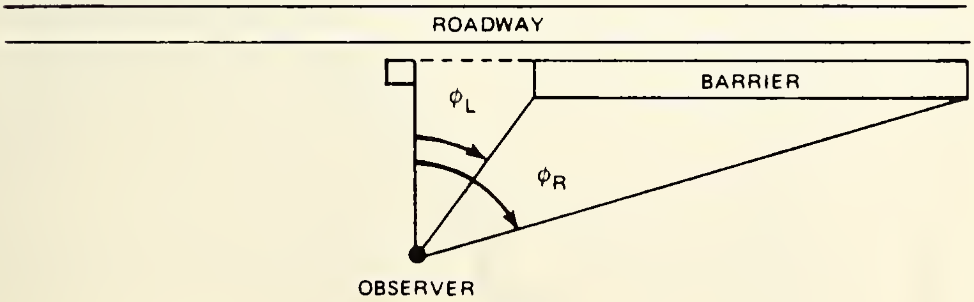
For infinitely long barriers, i.e., $\phi_L = -90°$ and $\phi_R = +90°$, the attenuation provided by the barrier can be read from Figure 11 for positive values of N_o. For negative values of N_o, see Figure 12. Figures 11 and 12 are based on the tables in Appendix B using $\phi_L = -90°$ and $\phi_R = +90°$.



(1) CASE A



(2) CASE B



(3) CASE C

Figure 10. Angle Identification of Barriers

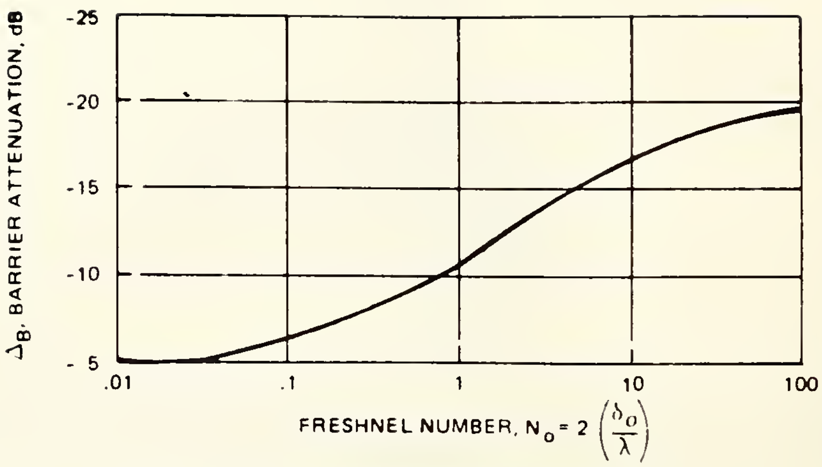


Figure 11. Barrier Attenuation vs Fresnel Number, N_o, for Infinitely Long Barriers

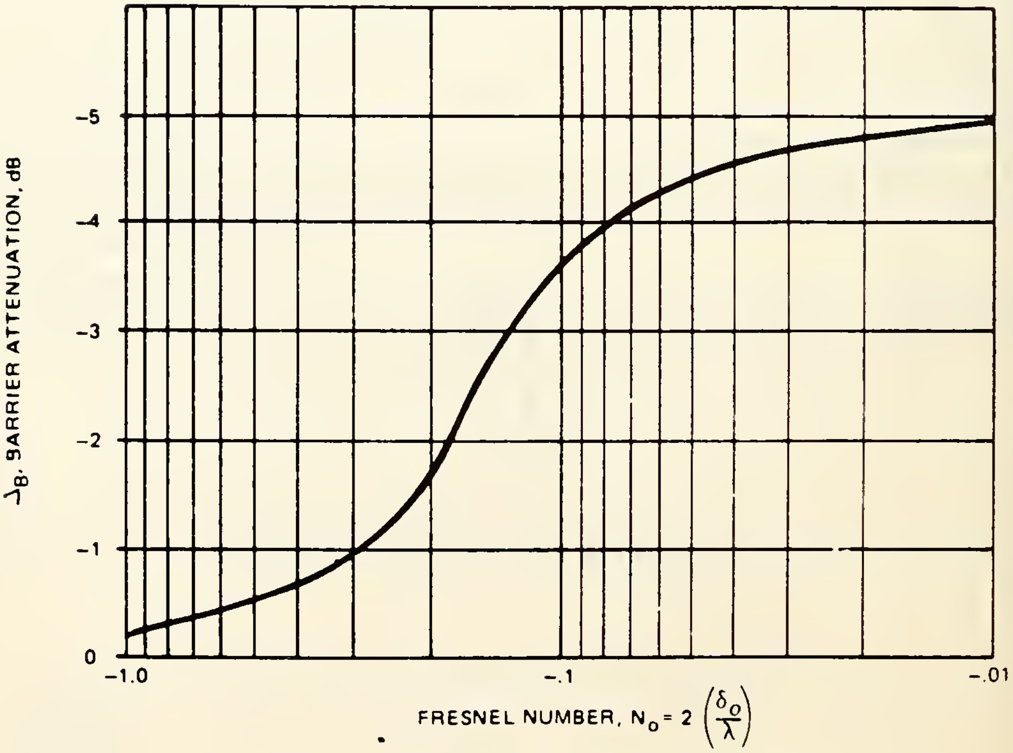


Figure 12. Barrier Attenuation vs Negative Fresnel Number, N_o, for Infinitely Long Barriers

2. WORKSHEETS

MODEL #1 WORKSHEETS

MODEL 1

NAME
DATE
PROJECT

Existing Case

		LINK # 1			LINK # 2			
Lane No./Road Segment								
Vehicle Class		A	MT	HT	A	NT	HT	
N (vph)		382	54	13	286	40	10	D/E
S (kph)		65	65	65	50	50	50*	D
D (m)			59			75		M
ϕ_1 (degrees)	FIG 5		-55			-55		Es
ϕ_2 (degrees)	FIG 5		+40			+30		Es
$(L_o)E_i$ (dBA)	FIG 2	66.7	77.9	83.1	62.3	74.0	80.3	
10 LOG $(N_i D_o / S_i)$ dB	FIG 3	+19.5	11.0	4.8	19.3	10.8	4.8	
10 LOG (D_o/D) dBA	FIG 4							
15 LOG (D_o/D) dBA	FIG 4	-8.9	-8.9	-8.9	-10.5	-10.5	-10.5	
10 LOG $(\psi_o(\phi_1, \phi_2)/\pi)$	FIG 6							
10 LOG $(\psi_{12}(\phi_1, \phi_2)/\pi)$	FIG 7	-3.2	-3.2	-3.2	-3.5	-3.5	-3.5	
ϕ_L (degrees)	FIG 10							
ϕ_R (degrees)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		49.1	51.8	50.8	42.6	45.8	46.7	
Leq(h) dBA			55.9			49.9		
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - L_{eq})_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

drop decimal vehicles

A : assumed
D : Parsons data
M : Measured
E : ERT data
Es : Estimated
* = 50 km/h assumed (minimum)

NAME ALTB
DATE 8/23
PROJECT 070

① Existing Case

		Link #3			Link #4	
1. Lane No./Road Sagmant		Link #3			Link #4	
2. Vahicla Class		A	MT	HT	A	NT
3. N (vph)		668	94	24	200	28
4. S (kph)			50*			50*
5. D (m)		/	90	/	/	170
6. Φ_1 (dagraas)	FIG 5	/	-57	/	/	+22
7. Φ_2 (dagraas)	FIG 5	/	-22	/	/	+42
8. $(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	62.3	74.0
9. 10 LOG $(N_i D_o / S_i)$ dB	FIG 3	23.0	14.5	8.6	17.8	9.2
10a. 10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/
10b. 15 LOG (D_o/D) dBA	FIG 4	-11.7	-11.7	-11.7	-15.8	-15.8
11a. 10 LOG $(\Psi_o(\Phi_1, \Phi_2)/\pi)$	FIG 6	/	/	/	/	/
11b. 10 LOG $(\Psi_{12}(\Phi_1, \Phi_2)/\pi)$	FIG 7	-7.7	-7.7	-7.7	-9.8	-9.8
12. Φ_L (degraas)	FIG 10					
13. Φ_R (dagraas)	FIG 10					
14. δ_o (m)	FIG 9					
15. N_o	EQ 18					
16. Δ_B (dBA)	App B					
17. CONSTANT (dB)		-25	-25	-25	-25	-25
18. Leq(h) (dBA)		40.9	44.1	44.5	29.5	32.6
19. Leq(h) dBA		/	48.2	/	/	36.7
20. Δ_s dBA	FIG 8					
21. Leq(h) dBA						
22. Leq(h) dBA						
23. ND/S (m/km)						
24. $(L_{10} - Leq)_i$ dBA	FIG 15					
25. L_{10} (h) dBA						
26. L_{10} (h) dBA						
27. L_{10} (h) dBA						

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km/

NAME Peggy
DATE
PROJECT

①

Existing Case

Lane No./Road Segment		LINK #5			Link #6			
Vehicle Class		A	MT	HT	A	NT	HT	
N (vph)		867	122	31	3060	432	108	P/E
S (kph)		50	50	50*	89	89	89	P
D (m)		[illegible]	195	155		160		M
Φ_1 (degrees)	FIG 5		−10			0		Es
Φ_2 (degrees)	FIG 5		+35			+42		Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	71.8	82.5	86.4	
$10 \log(N_i D_o / S_i)$ dB	FIG 3	24.1	15.6	9.6	27.1	18.6	12.6	
$10 \log(D_o/D)$ dBA	FIG 4							
$15 \log(D_o/D)$ dBA	FIG 4	−14.8	−14.8	−14.8	−15.4	−15.4	−15.4	
$10 \log(\Psi_o(\Phi_1,\Phi_2)/\pi)$	FIG 6							
$10 \log(\Psi_{12}(\Phi_1,\Phi_2)/\pi)$	FIG 7	−6	−6	−6	−6.5	−6.5	−6.5	
Φ_L (degrees)	FIG 10							
Φ_R (degrees)	FIG 10							
δ_o (m)	FIG 9		45.8			46.9		
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		−25	−25	−25	−25	−25	−25	
Leq(h) (dBA)		40.6	43.8	44.1	52.0	54.2	52.4	
Leq(h) dBA			47.9			57.7		
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - Leq)_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated
* = minimum 50 km/h

NAME JMB
DATE
PROJECT 020

EXISTING CA

			LINK 1			LINK	
1.	Lane No./Road Segment						
2.	Vehicle Class		A	MT	HT	A	NT
3.	N (vph)		3060	432	108	1022	144
4.	S (kph)			89			50*
5.	D (m)			183			122
6.	ϕ_1 (degrees)	FIG 5		-02			+10
7.	Φ_2 (degrees)	FIG 5		+25			+42
8.	$(L_o)_{Ei}$ (dBA)	FIG 2	71.8	82.5	66.4	62.3	[illegible]
9.	$10 \log (N_i D_o / S_i)$ dB	FIG 3	37.1	18.6	12.6	24.8	16.3
10a.	$10 \log (D_o/D)$ dBA	FIG 4					
10b.	$15 \log (D_o/D)$ dBA	FIG 4	-16.3	[illegible]	-16.3	-13.6	[illegible]
11a.	$10 \log (\Psi_o(\phi_1, \phi_2)/\pi)$	FIG 6					
11b.	$10 \log (\Psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7	[illegible]	[illegible]	-8.2	-7.7	-7.7
12.	ϕ_L (degrees)	FIG 10					
13.	ϕ_R (degrees)	FIG 10					
14.	δ_o (m)	FIG 9					
15.	N_o	EQ 18					
16.	Δ_B (dBA)	App B					
17.	CONSTANT (dB)		-25	-25	-25	-25	-25
18.	$L_{eq}(h)$ (dBA)		[illegible]	51.0	48.9	40.8	[illegible]
19.	$L_{eq}(h)$ dBA			54.5			53.1
20.	Δ_s dBA	FIG 8					
21.	$L_{eq}(h)$ dBA						
22.	$L_{eq}(h)$ dBA						
23.	ND/S (m/km)						
24.	$(L_{10} - L_{eq})_i$ dBA	FIG 15					
25.	$L_{10}(h)$ dBA						
26.	$L_{10}(h)$ dBA						
27.	$L_{10}(h)$ dBA						

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km

NAME MTB
DATE
PROJECT

①

EXISTING CASE

		LINK 9			LINK 10			
Lane No./Road Segment								
Vehicle Class		A	MT	HT	A	MT	HT	
N (vph)		337	48	12	1415	800	50	P/E
S (kph)			50*			50*		P
D (m)		/	12.9	/	/	223	/	M
Φ_1 (degrees)	FIG 5	/	+16	/	/	+17	/	Es
Φ_2 (degrees)	FIG 5	/	+35	/	/	+38	/	Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	62.3	74.0	80.3	
$10 \log (N_i D_o / S_i)$ dB	FIG 3	20.0	11.6	5.6	26.3	27.8	11.8	
$10 \log (D_o/D)$ dBA	FIG 4	/	/	/	/	/	/	
$15 \log (D_o/D)$ dBA	FIG 4	-14.0	-14.0	-14.0	-17.6	-17.6	-17.6	
$10 \log (\psi_o(\Phi_1, \Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
$10 \log (\psi_{1/2}(\Phi_1, \Phi_2)/\pi)$	FIG 7	-9.6	-9.6	-9.6	-9.4	-9.4	-9.4	
Φ_L (degrees)	FIG 10							
Φ_R (degrees)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		53.7	37.0	37.3	36.6	49.8	40.1	
Leq(h) dBA		/	41.0	/	/	50.[illegible]	/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - L_{eq})_i$ dBA	FIG 15							
$L_{10}(h)$ dBA								
$L_{10}(h)$ dBA								
$L_{10}(h)$ dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

(1)

NAME NTB
DATE
PROJECT 620

EXISTING CAS

			LINK 11			LINK 12	
			A	MT	HT	A	NT
1.	Lane No./Road Segment						
2.	Vehicle Class						
3.	N (vph)		1022	144	36	650	92
4.	S (kph)			50*			50*
5.	D (m)		/	134	/	/	229
6.	Φ_1 (degrees)	FIG 5	/	-5	/	/	-50
7.	Φ_2 (degrees)	FIG 5	/	+65	/	/	-33
8.	$(L_o)E_i$ (dBA)	FIG 2	67.3	74.0	80.3	67.3	74.0
9.	$10 \log (N_i D_o / S_i)$ dB	FIG 3	24.9	16.3	10.3	22.9	14.4
10a.	$10 \log (D_o/D)$ dBA	FIG 4	/	/	/	/	/
10b.	$15 \log (D_o/D)$ dBA	FIG 4	-14.2	-14.2	-14.2	17.7	-17.7
11a.	$10 \log (\Psi_o(\Phi_1,\Phi_2)/\pi)$	FIG 6	/	/	/	/	/
11b.	$10 \log (\Psi_{1/2}(\Phi_1,\Phi_2)/\pi)$	FIG 7	-4.6	-4.6	-4.6	[illegible]	[illegible]
12.	Φ_L (degrees)	FIG 10					
13.	Φ_R (degrees)	FIG 10					
14.	$\hat{d}_o$ (m)	FIG 9					
15.	N_o	EQ 18					
16.	Δ_B (dBA)	App B					
17.	CONSTANT (dB)		-25	-25	-25	-25	-25
18.	Leq(h) (dBA)		43.4	46.5	46.5	29.9	35.1
19.	Leq(h) dBA		/	50.6	/	/	39.1
20.	Δ_s dBA	FIG 8					
21.	Leq(h) dBA						
22.	Leq(h) dBA						
23.	ND/S (m/km)						
24.	$(L_{10} - Leq)_i$ dBA	FIG 15					
25.	L_{10}(h) dBA						
26.	L_{10}(h) dBA						
27.	L_{10}(h) dBA						

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated da
* = Minimum 50 km

NAME
DATE
PROJECT

①

		EXISTING [illegible]						
		LINK 13			LINK 14			
Lane No. /Road Segment								
Vehicle Class		A	MT	HT	A	MT	HT	
N (vph)		467	66	16	467	66	16	P/E
S (kph)			50*			50*		P
D (m)		/	247	/	/	241	/	M
ϕ_1 (degrees)	FIG 5	/	[illegible]	/	/	[illegible]	/	Es
ϕ_2 (degrees)	FIG 5	/	-14	/	/	[illegible]	/	Es
$(L_o)E_i$ (dBA)	FIG 2	[illegible]	74.0	80.7	[illegible]	[illegible]	[illegible]	
$10 \log(N_i D_o / S_i)$ dB	FIG 3	21.4	[illegible]	6.8	21.4	13.0	[illegible]	
$10 \log(D_o/D)$ dBA	FIG 4	/	/	/	/	/	/	
$15 \log(D_o/D)$ dBA	FIG 4	-17.7	-17.7	-17.7	-18.1	[illegible]	-18.1	
$10 \log(\psi_0(\phi_1, \phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
$10 \log(\psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ϕ_L (degrees)	FIG 10							
ϕ_R (degrees)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) dBA		31.3	31.7	34.2	32.6	35.9	36.0	
Leq(h) dBA		/	38.5	/	/	39.8	/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - L_{eq})_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

①

NAME MTB
DATE
PROJECT 020

EXISING CASE

LINK 15

			A	MT	HT	A	MT	H
1.	Lane No./Road Sagment							
2.	Vehicle Class		A	MT	HT	A	MT	H
3.	N (vph)		650	92	23			
4.	S (kph)			50*				
5.	D (m)		/	241	/	/		/
6.	Φ_1 (degrees)	FIG 5	/	-49	/	/		/
7.	Φ_2 (degrees)	FIG 5	/	-34	/	/		/
8.	$(L_o)Ei$ (dBA)	FIG 2	67.3	74.0	80.3			
9.	$10 \text{ LOG } (N_i D_o / S_i)$ dB	FIG 3	20.9	14.4	8.4			
10a.	$10 \text{ LOG } (D_o/D)$ dBA	FIG 4	/	/	/	/	/	/
10b.	$15 \text{ LOG } (D_o/D)$ dBA	FIG 4	-18.1	-18.1	-18.1			
11a.	$10 \text{ LOG } (\Psi_o(\Phi_1, \Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	$10 \text{ LOG } (\Psi_{1/2}(\Phi_1, \Phi_2)/\pi)$	FIG 7	-10.7	-10.7	-10.7			
12.	Φ_L (degrees)	FIG 10						
13.	Φ_R (degrees)	FIG 10						
14.	δ_o (m)	FIG 9						
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-25
18.	Leq(h) (dBA)		31.4	34.6	34.9			
19.	Leq(h) dBA		/	37.9	/	/		/
20.	Δ_s dBA	FIG 8						
21.	Leq(h) dBA							
22.	Leq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10} - Leq)_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated da
* = Minimum 50 km h

MODEL #2 WORKSHEETS

OINT SOURCE TREATMENT : (LINKS 4, 10, 6, 7)

If $\Delta\phi \leq 25°$, Link is treated as point source

$D_i = \sqrt{D_N D_F}$ where D_N = Distance (meters) to near end of Link

D_F = Distance to far end of Link

Formula $20 \log \frac{D_o}{D_i}$ is then applied to yeild distance correction

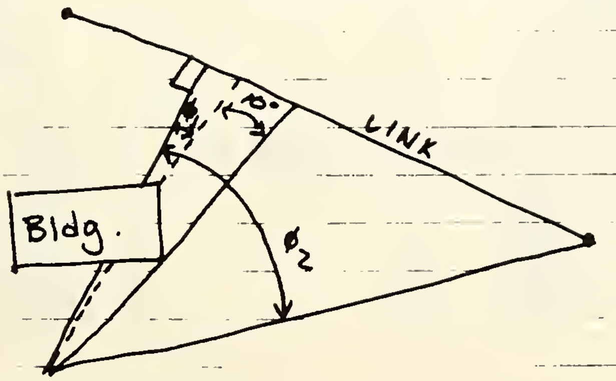
$D_o = 15$

20 LOG = attenuation for point source

The finite roadway correction is dropped

RRIER CORRECTION : (LINKS 11, 12, 15)

ϕ_1 is assumed to be 10° beyond the angle of the corner of the building. ie:



This is because the building is too tall to treat in the FHWA manner, where barrier height determines the degree of attenuation.

Model #2
Existing Case

NAME
DATE
PROJECT

1.	Lane No./Road Segment		LINK #1			LINK #		
2.	Vehicle Class		A	MT	HT	A	MT	h
3.	N (vph)		382	54	13	286	40	
4.	S (kph)		-	65	-	-	50*	-
5.	D (m)		/	135	/	/	75	/
6.	Φ_1 (degrees)	FIG 5	/	-57	/	/	-70	/
7.	Φ_2 (degrees)	FIG 5	/	-15	/	/	-45	/
8.	$(L_o)E_i$ (dBA)	FIG 2	[illegible]	77.9	73.1	[illegible]	[illegible]	7
9.	10 LOG $(N_i D_o / S_i)$ dB	FIG 3	19.5	11.0	4.8	19.3	10.8	4
10a.	10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/	/
10b.	15 LOG (D_o/D) dBA	FIG 4	-14.3	-14.3	-14.3	-10.5	-10.5	-1
11a.	10 LOG $(\Psi_o(\Phi_1, \Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	10 LOG $(\Psi_{1/2}(\Phi_1, \Phi_2)/\pi)$	FIG 7	-6.8	-6.8	-6.8	-10.0	-10.0	-1
12.	Φ_L (degrees)	FIG 10						
13.	Φ_R (degrees)	FIG 10						
14.	δ_o (m)	FIG 9						
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-2
18.	Leq(h) (dBA)		40.1	42.8	41.8	36.1	39.3	39
19.	Leq(h) dBA		/	46.5	/	/	43.4	/
20.	Δ_S dBA	FIG 8						
21.	Leq(h) dBA							
22.	Leq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10} - Leq)_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km/

Model #2
Existing Case

NAME
DATE
PROJECT

Lane No./Road Segment		LINK #3			LINK #4			
Vehicle Class		A	MT	HT	A	MT	HT	
N (vph)		668	94	24	~~300~~	~~28~~	~~7~~	P/E
S (kph)		-	50*	-	~~-~~	~~50*~~	~~-~~	P
D (m)		/	169	/	/		/	M
ϕ_1 (degrees)	FIG 5	/	+15	/	/	~~-85~~	/	Es
ϕ_2 (degrees)	FIG 5	/	+45	/	/	~~-80~~	/	Es
$(L_o)_{Ei}$ (dBA)	FIG 2	62.3	74.0	80.3	~~62.3~~	~~74.0~~	~~80.3~~	
10 LOG $(N_i D_o / S_i)$ dB	FIG 3	23.0	14.5	8.6	~~17.7~~	[illegible]	~~3.2~~	
10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/	/	
15 LOG (D_o/D) dBA	FIG 4	-15.8	-15.8	-15.8	~~-1.2~~	~~-1.2~~	~~-1.2~~	
10 LOG $(\psi_o(\phi_1,\phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
10 LOG $(\psi_{1/2}(\phi_1,\phi_2)/\pi)$	FIG 7	-8.1	-8.1	-8.1	-	[illegible]		
ϕ_L (degrees)	FIG 10							
ϕ_R (degrees)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	~~-25~~	~~-25~~	~~-25~~	
Leq(h) (dBA)		36.4	39.6	40.0	~~35.4~~	~~38.5~~	~~38.8~~	
Leq(h) dBA		/	43.7	/	/	~~42.6~~	/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - L_{eq})_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

Modal #2
Existing Case
POINT SOURCE

NAME
DATE
PROJECT

1. Lane No./Road Sagment		LINK#A			~~[illegible]~~		
2. Vahicle Class		A	MT	HT	A	MT	H
3. N (vph)		200	28	11			
4. S (kph)			50*				
5. D (m)		/	216	/	/		/
6. Φ_1 (dagraas)	FIG 5	/		/	/		/
7. Φ_2 (dagraas)	FIG 5	/		/	/		/
8. $(L_o)E_i$ (dBA)	FIG 2	[illegible]	74.5	50.3			
9. 10 LOG $(N_i D_o/S_i)$ dB	FIG 3	15.8	9.2	[illegible]			
10a. 10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/	/
10b. 20 ~~15~~ LOG (D_o/D) dBA	FIG 4		-23.2				
11a. 10 LOG $(\Psi_o(\Phi_1,\Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b. 10 LOG $(\Psi_{1/2}(\Phi_1,\Phi_2)/\pi)$	FIG 7						
12. Φ_L (degraas)	FIG 10						
13. Φ_R (dagraas)	FIG 10						
14. δ_o (m)	FIG 9						
15. N_o	EQ 18						
16. Δ_B (dBA)	App B						
17. CONSTANT (dB)		-25	-25	-25	-25	-25	-2
18. Leq(h) (dBA)		31.9	35	35.5			
19. Leq(h) dBA		/	31.1	/	/		/
20. Δ_s dBA	FIG 8						
21. Leq(h) dBA							
22. Leq(h) dBA							
23. ND/S (m/km)							
24. $(L_{10}-Leq)_i$ dBA	FIG 15						
25. L_{10} (h) dBA							
26. L_{10} (h) dBA							
27. L_{10} (h) dBA							

$D_i = \sqrt{D_N D_F}$

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km h

Model #2
Existing Case

NAME
DATE
PROJECT

Lane No./Road Segment		LINK #5			LINK #6			
Vehicle Class		A	MT	HT	A	NT	HT	
N (vph)		867	122	31	3060	432	107	P/E
S (kph)		-	50*	-	-	89	-	P
D (m)			67			46		M
ϕ_1 (degrees)	FIG 5		-65			-90		Es
ϕ_2 (degrees)	FIG 5		-25			-55		Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	71.9	[illegible]	[illegible].4	
$10 \log(N_i D_o / S_i)$ dB	FIG 3	24.1	15.6	9.6	27.1	[illegible]	[illegible]	
$10 \log(D_o/D)$ dBA	FIG 4							
$15 \log(D_o/D)$ dBA	FIG 4	-9.7	-9.7	-9.7	-7.3	-7.3	-7.3	
$10 \log(\psi_o(\phi_1, \phi_2)/\pi)$	FIG 6							
$10 \log(\psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7	-7.2	-7.2	-7.2	-10.5	-10.5	-10.5	
ϕ_L (degrees)	FIG 10							
ϕ_R (degrees)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		45.2	48.4	48.7	56.1	58.3	56.2	
Leq(h) dBA			52.5			61.7		
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - Leq)_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

MODEL 2 —

POINT SOURCE TREA

NAME
DATE
PROJECT

			LINK 6			LINK 7		
			A	MT	HT	A	NT	H
1.	Lane No./Road Segment							
2.	Vehicle Class							
3.	N (vph)		3060	432	108	3060	432	10
4.	S (kph)			89			89	
5.	D (m)		/	160	/	/	159	/
6.	ϕ_1 (degrees)	FIG 5	/		/	/		/
7.	ϕ_2 (degrees)	FIG 5	/		/	/		/
8.	$(L_o)E_i$ (dBA)	FIG 2	71.8	82.5	86.4	71.8	82.5	
9.	$10 \log(N_i D_o / S_i)$ dB	FIG 3	27.1	18.6	12.6	27.1	18.6	12
10a.	$10 \log(D_o/D)$ dBA	FIG 4	/	/	/	/	/	/
10b.	20 ~~10~~ $\log(D_o/D)$ dBA	FIG 4		-20.6			-20.5	
11a.	$10 \log(\psi_o(\phi_1, \phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	$10 \log(\psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7						
12.	ϕ_L (degrees)	FIG 10						
13.	ϕ_R (degrees)	FIG 10						
14.	δ_o (m)	FIG 9		45.6			4	
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-2
18.	Leq(h) (dBA)		53.3	55.5	53.4	53.4	55.6	53
19.	Leq(h) dBA		/	59.0	/	/	59.1	/
20.	Δ_s dBA	FIG 8						
21.	Leq(h) dBA							
22.	Leq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10} - L_{eq})_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

$D_i = \sqrt{D_N D_F}$

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated da
* = Minimum 50 km

NAME
DATE
PROJECT

Model # 2
Existing Case

Lane No./Road Sagmant		LINK #7			LINK #8			
Vahicle Class		A	MT	HT	A	MT	HT	
N (vph)		3060	432	108	1022	144	36	P/E
S (kph)		-	89	-	-	50*	-	P
D (m)		/	36	/	/	66	/	M
ϕ_1 (degraes)	FIG 5	/	-90	/	/	+40	/	Es
ϕ_2 (degraes)	FIG 5	/	-65	/	/	+65	/	Es
$(L_o)Ei$ (dBA)	FIG 2	71.8	[illegible]	86.4	62.3	74.0	[illegible]	
10 LOG $(N_i D_o/S_i)$ dB	FIG 3	27.1	18.6	12.6	24.8	16.3	10.3	
10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/	/	
15 LOG (D_o/D) dBA	FIG 4	-5.7	-9.7	-5.7	-9.7	-9.7	-9.7	
10 LOG $(\Psi_o(\phi_1,\phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
10 LOG $(\Psi_{1/2}(\phi_1,\phi_2)/\pi)$	FIG 7		[illegible]			-10.2		
ϕ_L (degraes)	FIG 10							
ϕ_R (degraes)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		[illegible]	[illegible]	55.3	42.2	45.4	[illegible]	
Leq(h) dBA		/	59.4	/	/	49.5	/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10}-Leq)_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

Model # 2
Existing Case

NAME
DATE
PROJECT

			LINK #9			LINK #1	
1.	Lane No./Road Segment						
2.	Vehicle Class		A	MT	HT	A	NT
3.	N (vph)		337	48	12	1415	200
4.	S (kph)		–	50*	–	–	50*
5.	D (m)		/	72	/	/	167
6.	ϕ_1 (degrees)	FIG 5	/	-55	/	/	+30
7.	ϕ_2 (degrees)	FIG 5	/	+35	/	/	[illegible]
8.	$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	62.3	74.0
9.	$10 \log (N_i D_o / S_i)$ dB	FIG 3	20.0	11.6	5.6	26.3	27.7
10a.	$10 \log (D_o/D)$ dBA	FIG 4	/	/	/	/	/
10b.	$15 \log (D_o/D)$ dBA	FIG 4	–	-10.2	–	–	[illegible]
11a.	$10 \log (\psi_o(\phi_1,\phi_2)/\pi)$	FIG 6	/	/	/	/	/
11b.	$10 \log (\psi_{1/2}(\phi_1,\phi_2)/\pi)$	FIG 7		-3.2			
12.	ϕ_L (degrees)	FIG 10					
13.	ϕ_R (degrees)	FIG 10					
14.	δ_o (m)	FIG 9					
15.	N_o	EQ 18					
16.	Δ_B (dBA)	App B					
17.	CONSTANT (dB)		-25	-25	-25	-25	-25
18.	Leq(h) (dBA)		43.9	47.2	47.5	42.7	55.9
19.	Leq(h) dBA		/	51.2	/	/	36.5
20.	Δ_S dBA	FIG 8					
21.	Leq(h) dBA						
22.	Leq(h) dBA						
23.	ND/S (m/km)						
24.	$(L_{10} - L_{eq})_i$ dBA	FIG 15					
25.	L_{10} (h) dBA						
26.	L_{10} (h) dBA						
27.	L_{10} (h) dBA						

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km/h

Model #2
Existing Cost

NAME
DATE
PROJECT

Lane No./Road Sagment		LINK # 11			LINK #12			
Vahicla Class		A	MT	HT	A	MT	HT	
N (vph)		1022	144	36	650	92	23	P/E
S (kph)		-	50*	-	-	50*	-	P
D (m)		/	55	/	/	216	/	M
Φ_1 (dagraas)	FIG 5	/	-60†	/	/	0†	/	Es
Φ_2 (dagraas)	FIG 5	/	+70	/	/	+15	/	Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	75.5	62.3	74.0	[illegible]	
$10 \text{ LOG} (N_i D_o / S_i)$ dB	FIG 3	24.9	16.3	10.3	22.7	14.4	7.4	
$10 \text{ LOG} (D_o/D)$ dBA	FIG 4	/	/	/	/	/	/	
$15 \text{ LOG} (D_o/D)$ dBA	FIG 4		-8.5			-17.4		
$10 \text{ LOG} (\Psi_o(\Phi_1, \Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
$10 \text{ LOG} (\Psi_{1/2}(\Phi_1, \Phi_2)/\pi)$	FIG 7		-2.0			-10.7		
Φ_L (degraas)	FIG 10							
Φ_R (dagraas)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		31.7	54.8	55.1	32.1	35.3	35.6	
Leq(h) dBA		/	58.9	/	/	39.4	/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - L_{eq})_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km/h

Modal #2
Existing Casa.

NAME
DATE
PROJECT

			LINK #13			LINK #1		
1.	Lane No./Road Sagment							
2.	Vahicle Class		A	MT	HT	A	MT	H
3.	N (vph)		467	66	16	467	66	1
4.	S (kph)		-	50*	-	-	50*	-
5.	D (m)		/	216	/	/	226	/
6.	ϕ_1 (dagraas)	FIG 5	/	+15	/	/	+15	/
7.	ϕ_2 (dagraas)	FIG 5	/	+35	/	/	+35	/
8.	$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	62.3	74.0	0
9.	$10 \log(N_i D_o / S_i)$ dB	FIG 3	21.4	13.0	6.8	21.4	13.0	6
10a.	$10 \log(D_o/D)$ dBA	FIG 4	/	/	/	/	/	/
10b.	$15 \log(D_o/D)$ dBA	FIG 4		-17.4			-17.7	
11a.	$10 \log(\Psi_o(\phi_1,\phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	$10 \log(\Psi_{1/2}(\phi_1,\phi_2)/\pi)$	FIG 7		-0.5			-1.5	
12.	ϕ_L (degraas)	FIG 10						
13.	ϕ_R (dagraas)	FIG 10						
14.	δ_o (m)	FIG 9					3.	
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-2
18.	Leq(h) (dBA)		31.8	35.1	35.2	31.5	34.8	34
19.	Leq(h) dBA		/	39.2	/	/	38.7	/
20.	Δ_s dBA	FIG 8						
21.	Laq(h) dBA							
22.	Laq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10}-Laq)_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km h

Model #2
Existing Case

NAME
DATE
PROJECT

Lane No./Road Segment		LINK #15			LINK #16			
Vehicle Class		A	MT	HT	A	NT	HT	
N (vph)		650	92	23	612	86	22	P/E
S (kph)		-	50*	-		50*		P
D (m)		/	226	/	/	30	/	M
ϕ_1 (degrees)	FIG 5	/	$0^{\dagger}$	/	/	-75	/	Es
Φ_2 (degrees)	FIG 5	/	+15	/	/	+40	/	Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	70.3	62.3	74.0	70.3	
$10 \text{ LOG } (N_i D_o / S_i)$ dB	FIG 3	22.9	14.4	8.4	22.6	14.1	6.6	
$10 \text{ LOG } (D_o/D)$ dBA	FIG 4	/	/	/	/	/	/	
$15 \text{ LOG } (D_o/D)$ dBA	FIG 4		-17.7			-4.5		
$10 \text{ LOG } (\Psi_o(\phi_1, \phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
$10 \text{ LOG } (\Psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7		-10.7			-2.[illegible]		
ϕ_L (degrees)	FIG 10							
Φ_R (degrees)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		31.8	35.0	35.3	52.9	56.1	54.9	
Leq(h) dBA		/	39.1	/	/	59.6	/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - L_{eq})_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

† see LINK #11, 12

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

Model #2
Existing Case

NAME
DATE
PROJECT

			LINK #7					
1.	Lane No./Road Segment							
2.	Vehicle Class		A	MT	HT	A	MT	H
3.	N (vph)		306	43	11			
4.	S (kph)		–	50*	–			
5.	D (m)		/	64	/	/		/
6.	Φ_1 (degrees)	FIG 5	/	-45	/	/		/
7.	Φ_2 (degrees)	FIG 5	/	+5	/	/		/
8.	$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3			
9.	$10 \log(N_i D_o/S_i)$ dB	FIG 3	19.6	12.9	5.2			
10a.	$10 \log(D_o/D)$ dBA	FIG 4	/	/	/	/	/	/
10b.	$15 \log(D_o/D)$ dBA	FIG 4		-9.5				
11a.	$10 \log(\Psi_o(\Phi_1,\Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	$10 \log(\Psi_{1/2}(\Phi_1,\Phi_2)/\pi)$	FIG 7		-5.8				
12.	Φ_L (degrees)	FIG 10						
13.	Φ_R (degrees)	FIG 10						
14.	δ_o (m)	FIG 9						
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-2
18.	Leq(h) (dBA)		41.6	46.6	45.2			
19.	Leq(h) dBA		/	49.7	/	/		/
20.	Δ_s dBA	FIG 8						
21.	Leq(h) dBA							
22.	Leq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10}-L_{eq})_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km/h

APPENDIX E

RAIL NOISE CALCULATIONS

MODEL #1 RAIL NOISE

A. For Shore Line Rail

$L_{AE} \simeq 84$ dB (@ 50M) (observed during measurement period)

$N_{24 hr.} = 102$ train movements (EIR)

$N_{PH} \cong 20$ assumed

N_{PB} pass-by duration $\simeq 3$ sec. assumed

$$Leq_{PH} = 10 \text{ LOG} \left(\frac{1}{3600} \text{ sec/hr} \right) (N_{PH}) (N_{PB}) \, 10^{L_{AE}/10}$$

$$Leq_{PH} = 10 \text{ LOG } \frac{1}{3600} (20)(3)(10^{8.4})$$

$$Leq_{PH} = 10 \text{ LOG } \frac{10^{8.4}}{60}$$

$Leq_{PH} = 66.2$ dB @ 50 M

$$LEQ_{24} = LAE + 10 \text{ LOG} N - 49$$

$$LEQ_{24} = 84 + 10 \text{ LOG} (102) - 49$$

$LEQ_{24} = 55.1$ dB @ 50 M

B. For B & A Rail

$Leq_{24} = L_{AE} + 10 \text{ LOG } N - 49$

$L_{AE} = 75 \text{ dB}$ (observed during measure
@ 134 m)

$N = 20$ EIR

$Leq_{24} = 75 + 10 \text{ LOG } 20 - 49$

$Leq_{24} = 39 \text{ dB}$ @ 134 M -negligible

C. For Back Bay Idling

$L_{AE} \cong 64 \text{ dBA}$ for minute per train @ 14

or $122 \times 1 \text{ min} = 2 \text{ hrs}$

$Leq_{24} = 10 \text{ LOG } \frac{1}{N} \Sigma n_i \, 10^{L_i/10}$

$Leq_{24} = 10 \text{ LOG } \frac{1}{24 \text{ hrs/day}} \Sigma (2)(10^{6.5})$

$Leq_{24} = 54.2 \text{ dBA}$

$Leq_{PH} = 10 \text{ LOG } \frac{1}{60 \text{ min/hr}} (122)(\frac{1}{5})(10^{6.4})$

$Leq_{PH} = 59.1$ @ 143 M.

of trains duri
peak hour

MODEL #2 RAIL NOISE

$20 \text{ LOG } \frac{D_O}{D_1}$ = correction factor

Shore-line

$L_{eq(PH)} = 66.2$ dBA @ 50 M

$D_o = 50$ M

$D_i = 241$ M

$20 \text{ LOG } \frac{50}{241} = -13.7$

$L_{eq(PH)} = 66.2 - 13.7 = \boxed{52.5 \text{ dBA}}$

B & A

$L_{eq(PH)} = 39$ dBA @ 134 M

$D_o = 134$ M

$D_i = 149$ m

$20 \text{ LOG } \frac{134}{149} = -.92$

$L_{eq(PH)} = 39 - .92 = \boxed{38.8 \text{ dBA}}$

Back Bay Idling

$L_{eq(PH)} = 59.1$ @ 143 m

$D_o = 143$ m

$D_i = 149$ M

$20 \text{ LOG } \frac{143}{149} = -.36$

$L_{eq(PH)} = 59.1 - .36 = \boxed{58.7 \text{ dBA}}$

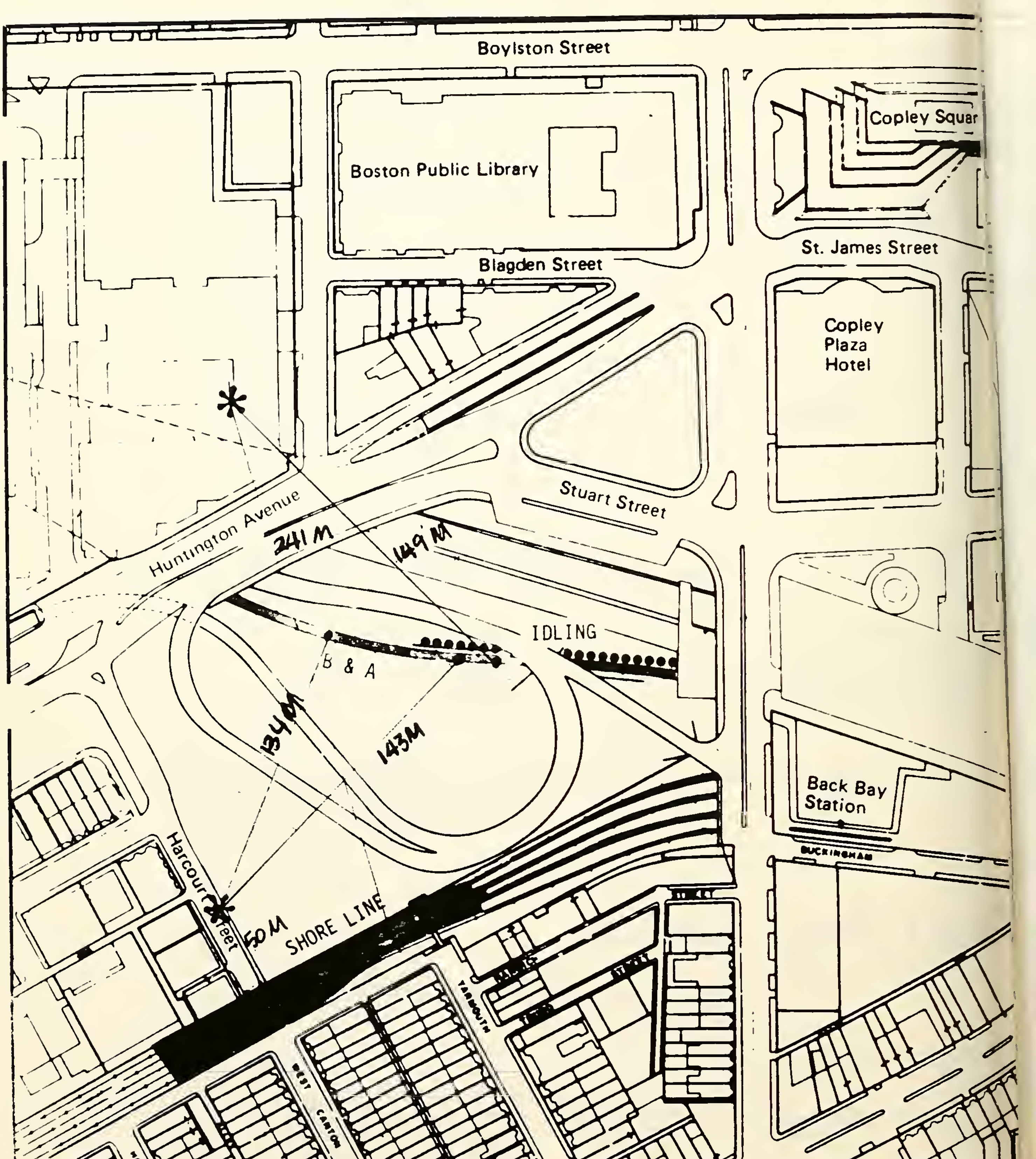


FIGURE 3.4 - LOCATIONS OF RAIL NOISE COMPONENTS

APPENDIX F

CONSTRUCTION EQUIPMENT SCHEDULE

CONSTRUCTION EQUIPMENT USE, BY TASK

COPLEY PLACE

	WATER MAIN RELOC.						HUNTINGTON AVE MODIFICATIONS		
	1	2	3	4	5	6	7	8	9
PROPOSED EQUIPMENT TYPE	DARTMOUTH ST/STUART	INFIELD	WIDEN RAMP D AND DETOUR TRAFFIC	RELOCATE UTILITIES STUART ST.	RELOCATE STUART ST. ON GRADE	RELOCATE STUART ST. ON STRUCTURE	BRIDGE AT STUART ST.	REGRADING AND BRIDGE MODIFICATIONS	TEMP RAMP & DETOUR TPL TRAFFIC
PILE DRIVERS/AUGERS						1	1		1
COMPRESSORS/JACKHAMMERS	1		1	2	1			1	
PUMPS		1				1			
BACKHOES	1	1		1		1	1		1
LOADERS			1		1	1	1	1	1
BULLDOZERS		1						1	1
CRANES						1	1		1
PAVING RIPPERS					1			1	
CHERRY PICKERS									
TRUCKS/TRAILERS	4	4	4	3	6	20	20	15	30
PAVERS	1		1	1	1			1	1
ROLLERS/COMPACTORS	1		1	1	1			1	1
CONCRETE TRUCKS						100	40	10	30
PERSONNEL/MATERIAL HOISTS									
FORKLIFTS									
MORTAR MIXERS									
CONCRETE PUMPS									
CRANE W/DEMOLITION BALL									
INDIVIDUAL JOB EQUIP TOTALS	8EA	7EA	8EA	8EA	11EA	125EA	64EA	32EA	67E

CONSTRUCTION EQUIPMENT USAGE, BY TASK

	WESTERN HOTEL			MARRIOTT HOTEL			
	10 SHEETING AND EXCAVATION	11 UNDERGROUND PARKING	12 SUPER STRUCTURE	1 EXCAVATION AND FOUNDATION	2 SERVICE RAMP AND PARKING	3 BALLROOM SUPERSTRUCT	4 LOBBY TOWER SUPERSTRUCT
1							
2	1			2	1		
3							
4	1			1			
5	1	1		1	1		
6	2	1		2	1		
7	1	1		1	1		
8	2	1	2	3	1	2	2
9							
10							
11	100	50	300	200	50	200	400
12							
13							
14		75	500	150	100	300	700
15			2			2	2
16			2			2	2
17			2			2	2
18						1	1
19							
20							
21							
22							
23							
24	108 EA	129 EA	808 EA	360 EA	155 EA	510 EA	1108 EA
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							
36							

CONSTRUCTION EQUIPMENT USAGE, BY TASK

	INFIELD									
	5 RNPIKE AMP OLITION	6 TURNPIKE NEW RAMP STRUCTURE	7 ACCESS RAMPS	8 INFIELD PARKING 101-124	9 INFIELD PARKING 124-141	10 SPECIALTY STORE & MALL ENTR	11 RETAIL AND MALL	12 OFFICES	1 HOUSING	3 TOTAL PROJECT EQUIP. TOTALS
1										
2	2	1		2					2	13 EA
3									1	7 EA
4				2						6 EA
5				1					1	12 EA
6	2			2					1	17 EA
7	1			1						9 EA
8		1	1	2	2	2	4	4	1	33 EA
9	1									3 EA
10				1	1	1	1		1	7 EA
11	30	50	20	250	250	200	500	500	100	3106 EA
12			1							7 EA
13			1							7 EA
14		100	30	500	500	300	500	600	700	4735 EA
15								4		10 EA
16				2	2	2	2	2	2	18 EA
17				2	2	2	2	2	2	18 EA
18				1	1	1	2	2	1	10 EA
19	1									1 EA
24	37 EA	152 EA	53 EA	766 EA	758 EA	508 EA	811 EA	1114 EA	311 EA	8019 EA

CONSTRUCTION EQUIPMENT, LOCATION SCHEDULE

	MONTH	1		2		3		4		
1	Pile Driver / Auger			(A1)	1	(A2)	2	(A1, B1)	2	(B1)
2	Compressor / Jackhammer	(A2)	2	(A4)	4			(A1)	1	
3	Pumps			(A1)	1	(A1, B1)	2	(A1 B1)	2	(A1,
4	Backhoes	(A1)	1	(A4)	4	(A3, B1)	4	(A2 B1)	3	
5	Loaders	(A1)	1	(A2)	2	(A1 B2)	3	(A2 B2)	4	A2
6	Bulldozers	(A1)	1	(A2)	2	(A1 B1)	2	(A1 B1)	2	
7	Cranes							(A1 B2)	3	A2
8	Paving Rippers							(A1)	1	(A1)
9	Cherry Pickers									
10	Trucks					(B1)	1	(B1)	1	(B1)
11	[illegible]			(A2)	2	(A1)	1			
12	[illegible] Compactors			(A2)	2	(A1)	1			
13	Concrete Trucks							(A1)	1	(A1)
14	Hoists									
15	Forklifts									
16	Mortar mixers									
17	Concrete pumps									
18	Demo - Crane									
19										
20										
21	TOTAL PIECES		5		18		16		20	
22										
23	A Subtotal		5		18		10		11	
24	B Subtotal		-		-		6		9	
25	C Subtotal		-		-		-		-	
26	D Subtotal		-		-		-		-	
27	E Subtotal		-		-		-		-	
28										
29										
30			24.1		93.4		95.1		95.5	
31										
32						# 1		L 2		
33										

4R21 · Buff
RM21 · Green

PAGE 1 of 6

CONSTRUCTION EQUIPMENT LOCATION SCHEDULE

MONTH

6		7		8		9		10		11		12		13	
	1	(A1)	1					(D4)	4	(D4,C1)	5	(C2)	2	(C3)	3
								(A1)	1	(A1)	1				
	1	(A1)	1	(A1)	1	(A1)	1	(A1)	1	(A1,C1,D2)	4	(C1,D2)	3	(C1,D2)	3
	1	(B1)	1					(A1C1D1)	3	(A1C1D1)	3	(D1)	1	(C1)	1
	1	(B1)	1					(A1C2D4)	7	(A1C2D4)	7	(A1D2)	3	(C1)	1
	1	(B1)	1					(A1C1D2)	4	(A1C1D2)	4	(A1D1)	2	(C1)	1
	2	(A3)	3	(A3B1)	4	(A31)	4	(B1)	1	(B1)	1	(C3D2)	5	(C3D2)	5
								(A1D1)	2	(A1)	1	(A1)	1		
								(A1)	1	(A1D1)	2	(A1D1)	2	(A1D2)	3
								(C1)	1	(C1)	1	(B1C1D1)	3	(B1C1D1)	3
	1					(A1)	1								
	1					(A1)	1								
	1	(A1)	1									(C1D1)	2	(C1D1)	2
												(D2)	2	(D2)	2
												(D2)	2	(D2)	2
												(D1)	1	(D1)	1
										(D1)	1	(D1)	1		
	10		9		5		7		25		29		30		27
	7		6		4		6		7		7		4		1
	3		3		1		1		1		1		1		1
	-		-		-		-		5		7		8		12
	-		-		-		-		12		14		17		13
	-		-		-		-								
	\		\		\		\		91.1		98.9		\		97.0
											D – 5				C 3

CONSTRUCTION EQUIPMENT LOCATION SCHEDULE

MONTH

14		15		16		17		18		19		20		21
(C1)	1							(D1)	1	(D1)	1			
(C1 D2)	3													
(C1)	1													
(C1)	1													
(C1)	1													
(B2C3D4)	9	(B2C4D4)	10	(B2C4D4)	10	(B2C4D5)	11	(B2C1D5)	8	(B2C1D5)	8	(B2C3D6)	11	(B2C3D
(A1D2)	3	(A1D2)	3	(A1D2)	3	(A1D2)	3	(D2)	2	(D2)	2	(D2)	2	(D2)
(B1C1D1)	3	(B1C1D1)	3	(B1C1D1)	3	(B1C1D1)	3	(B1C1D1)	3	(B1C1D1)	3	(B1C1D1)	3	(B1C1D
(B1C1D1)	3	(B1C2D1)	4	(B1C2D1)	4	(B1C1D1)	3	(B1C1D1)	3	(B1C1D1)	3	(B1C2D1)	4	(B1C1)
		(B2)	2	(B2)	2	(B2)	2	(B2)	2	(B2)	2	(B2)	2	(B2C2)
(B2D4)	6	(B2D4)	6	(B2D4)	6	(B2D4)	6	(B2D4)	6	(B2D4)	6	(B2C2D4)	8	(B2C2D
(D2)	2	(B2D4)	6	(B2D4)	6	(B2D4)	6	(B2D4)	6	(B2D4)	6	(B2C2D4)	8	(B2C2D
(D2)	2	(D2)	2	(D2)	2	(D2)	2	(D2)	2	(D2)	2	(D2)	2	(C1D2)
	35		36		36		36		33		33		40	
	1		1		1		1		–		–		–	
	6		10		10		10		10		10		10	
	10		7		7		6		3		3		10	
	18		18		18		19		20		20		20	

CONSTRUCTION EQUIPMENT LOCATION SCHEDULE

MONTH

2	23	24	25	26	27	28	29
						(E1) 1	(E1) 1
						(E1) 1	(E1) 1
						(E1) 1	(E1) 1
						(E1) 1	(E1) 1
D6) 13	(B2C5D6) 13	(B2C4D6) 12	(B2C4D5) 11	(B2C4D3) 9	(B2C4D3) 9	(B2C4D7) 13	(B2C2D7) 11
3	(C1D2) 3	(C1D2) 3	(C1D2) 3	(C1D1) 2	(C1D2) 3	(D2) 2	(D2E1) 3
D1) 3	(B1C1D1) 3	(B1C1D1) 3	(B1C1D1) 3	(B1C1D1) 3	(B1C1D1) 3	(B1C1D1) 3	(B1C1D1) 3
	(D1) 1						
	(D1) 1						
2	(B1C2) 3	(B1C2) 3	(B1C2) 3	(B1C2) 2	(C2) 2	(C1D1) 2	(C1D1) 2
2) 4	(B2C4) 6	(B2C4) 6	(B2C4) 6	(B2C4) 6	(B2C4) 6	(B2C4) 6	(B2C4) 6
10	(B2C4D4) 10	(B2C4D4) 10	(B2C4D4) 10	(B2C4D2) 8	(B2C4D2) 8	(B2C2D4) 8	(B2C2D4) 8
C2D4	(B2C4D4) 10	(B2C4D2) 8	(B2C4D2) 8	(B2C4D2) 8	(B2C2D2) 6	(B2C2D2) 6	(C2D2) 4
D2) 3	(C2D2) 4	(C2D2) 4	(C2D1) 3	(C2D1) 3	(C1D1) 2	(C1D3) 4	(C1D2) 3
46	54	48	47	41	38	48	44
–	–	–	–	–	–	–	–
10	10	10	10	10	9	9	7
17	23	22	22	22	19	15	13
19	21	17	15	9	17	20	19
						4	5
	96.1					96.6	96.2
						[illegible]	

CONSTRUCTION EQUIPMENT LOCATION SCHEDULE

30	31	32 MONTH	33	34	35	36	37
(B2C2D10E1) 15	(C2D10E1) 13	(C2D8E1) 11	(C2D8E1) 11	(C2D8E1) 11	(C2D8E1) 11	(C2D8E1) 11	(C2D8E1)
(D2E1) 3	(D2E1) 3	(D1E1) 2	(D1E1) 2	(D1E1) 2	(D1E1) 2	(D1E1) 2	(D1E1)
(C1D1) 2	(C1D1) 2	(C1) 1	(C1) 1	(C1) 1	(C1) 1	(C1) 1	(C1)
(C1D3E1) 5	(C1D3E1) 5	(C1D3E1) 5	(C1D3E1) 5	(C1D3E1) 5	(D3E1) 4	(D3E1) 4	(D2E1)
(C2D4) 6	(C2D4) 6	(C2D4) 6	(C2D4) 6	(D4) 4	(D4) 4	(D4) 4	(D4)
(C2D6E2) 12	(C2D5E2) 10	(C2D4E2) 8	(C2D4E2) 8	(C2D4E2) 8	(C2D4E2) 8	(C2D4E2) 8	(C2D4E2
(C2D2) 4	(C2D4E2) 8	(C2D4E2) 8	(C2D4E2) 8	(C2D4E2) 8	(C2D4E2) 8	(C2D2E2) 6	(D2E2)
(C1D4E1 6	(C1D4E1 6	(C1D4E1 6	(C1D4E1 6	(C1D4E1 6	(C1D4E1 6	(C1D4E1) 6	(D2E1)
51	53	47	47	45	44	42	
—	—	—	—	–	–	–	
2	—	–	—	—	–	—	
11	11	11	11	9	8	8	
32	34	28	28	28	28	26	
6	8	8	8	8	8	8	
	96.1						

CONSTRUCTION EQUIPMENT LOCATION SCHEDULE

39		MONTH		40		41	
(C2D8 E1)	11	(C2D8 E1)	7	(D4E1)	5	(D4E1)	5
(D1E1)	2	(E1)	1	(E1)	1	(E1)	1
(C1)	1	(E1)	1				
(D2E1)	3	(D2E1)	3	(D2E1)	3		
(D4)	4	(D4)	4	(D4)	4	(D4)	4
(C2D4E2)	8	(C2D2E2)	6	(D2E2)	4	(D2E2)	4
(D2E1)	3	(E1)	1				
	32		23		17		14
	–		–		–		–
	–		–		–		–
	5		5		–		–
	21		12		12		10
	6		6		5		4

APPENDIX G

CONSTRUCTION NOISE CALCULATIONS FOR EACH RECEPTOR

CONSTRUCTION NOISE MODEL SUMMARY

WITH IMPACT DEVICES

		RECEPTOR					
MODEL	MONTH	1	2	3	4	5	6
1	3	74.1	75.2	73.9	72.1	70.9	70.7
2	4	74.5	77.1*	74.0	72.2	71.1	70.9
3	13	77.9*	72.8	75.2	77.6	80.9	81.4*
4	23	75.6	68.8	74.5	75.0	77.9	78.2
5	11	77.8	74.9	80.4*	80.7*	79.7	78.5
6	28	70.2	68.5	74.3	79.8	85.5*	72.2

* Peak noise at receptor

CONSTRUCTION NOISE MODEL SUMMARY

WITHOUT IMPACT DEVICES

		RECEPTOR				
MODEL	MONTH	1	2	3	4	5
1	3	67.0	69.4	66.6	64.8	63.6
2	4	68.4	70.7*	68.0	67.5	65.1
3	13	71.1	70.5	72.9	73.5	73.3
4	23	75.6*	68.8	74.5*	75.0	77.9*
5	11	69.2	67.2	70.6	70.9	70.8
6	28	69.5	68.2	74.4	75.6*	77.9*

* Peak noise at receptor

CONSTRUCTION NOISE MODEL #1

MONTH 3, Peak @ Ⓐ

No Barriers

2) @ Site Center Ⓐ

	w/impact	w/o impact
2 pile drivers	@ 91 dBA x 2	omit
1 pump	@ 78	same
2 backhoes	@ 77 x 2	
1 loader	@ 75	
1 bulldozer	@ 76	
1 paver	@ 80	
1 roller / compactor	@ 74	
SUBTOTAL	94.7 dBA @ 50'	86.1 dBA

@ site Center Ⓑ

	w/impact	w/o impact
1 pump	@ 78	same
1 backhoe	@ 77	
2 loaders	@ 75 x 2	
1 bulldozer	@ 76	
1 truck	@ 75	
SUBTOTAL	83.9 dBA	83.9 dBA

MODEL C1 (with impact devices)

Leq @ Receptor $\boxed{1}$

Ⓐ $94.7 - 20 \text{ LOG } {}^{550}/_{50} = 94.7 - 20.9 = 73.8$

Ⓑ $83.9 - 20 \text{ LOG } {}^{595}/_{50} = 83.9 - 21.5 = 62.4$

Ⓒ ——

Ⓓ ——

Ⓔ ——

74.1 d

Leq @ Receptor $\boxed{2}$

Ⓐ $94.7 - 20 \text{ LOG } {}^{510}/_{50} = 94.7 - 20.2 = 74.5$

Ⓑ $83.9 - 20 \text{ LOG } {}^{355}/_{50} = 83.9 - 17.0 = 66.9$

75.2 dBA

Leq @ Receptor $\boxed{3}$

Ⓐ $94.7 - 20 \text{ LOG } {}^{560}/_{50} = 94.7 - 21.0 = 73.7$

Ⓑ $83.9 - 20 \text{ LOG } {}^{680}/_{50} = 83.9 - 22.7 = 61.2$

73.9

Leq @ Receptor $\boxed{4}$

Ⓐ $94.7 - 20 \text{ LOG } {}^{688}/_{50} = 94.7 - 22.8 = 71.7$

Ⓑ $83.9 - 20 \text{ LOG } {}^{840}/_{50} = 83.9 - 24.5 = 59.4$

72.1

MODEL C1, continued (with impact devices)

-eq @ Receptor $\boxed{5}$

Ⓐ $94.7 - 20\,\mathrm{LOG}\,{}^{795}/_{50} = 94.7 - 24.0 = 70.7$

Ⓑ $83.9 - 20\,\mathrm{LOG}\,{}^{945}/_{50} = 83.9 - 25.5 = \underline{58.4}$

70.9 dBA

Leq @ Receptor $\boxed{6}$

Ⓐ $94.7 - 20\,\mathrm{LOG}\,{}^{820}/_{50} = 94.7 - 24.3 = 70.4$

Ⓑ $83.9 - 20\,\mathrm{LOG}\,{}^{920}/_{50} = 83.9 - 25.3 = \underline{58.6}$

70.7 dBA

MODEL C1 (without impact devices)

Leq @ Receptor $\boxed{1}$

Ⓐ $86.1 - 20\ \mathrm{LOG}\ {}^{550}/_{50} = 86.1 - 20.9 = 65.2$

Ⓑ $83.9 - 20\ \mathrm{LOG}\ {}^{595}/_{50} = 83.9 - 21.5 = 62.4$

Ⓒ ——

Ⓓ ——

Ⓔ ——

67.0 d

Leq @ Receptor $\boxed{2}$

Ⓐ $86.1 - 20\ \mathrm{LOG}\ {}^{510}/_{50} = 86.1 - 20.2 = 65.9$

Ⓑ $83.9 - 20\ \mathrm{LOG}\ {}^{355}/_{50} = 83.9 - 17.0 = 66.9$

69.4 dBA

Leq @ Receptor $\boxed{3}$

Ⓐ $86.1 - 20\ \mathrm{LOG}\ {}^{559}/_{50} = 86.1 - 21.0 = 65.1$

Ⓑ $83.9 - 20\ \mathrm{LOG}\ {}^{680}/_{50} = 83.9 - 22.7 = 61.2$

66.6 dBA

Leq @ Receptor $\boxed{4}$

Ⓐ $86.1 - 20\ \mathrm{LOG}\ {}^{688}/_{50} = 86.1 - 22.8 = 63.3$

Ⓑ $83.9 - 20\ \mathrm{LOG}\ {}^{840}/_{50} = 83.9 - 24.5 = 59.4$

64.8

MODEL C1, continued (without impact)

@ Receptor $\boxed{5}$

Ⓐ $86.1 - 20 \log {}^{795}/_{50} = 86.1 - 24.0 = 62.1$

Ⓑ $83.9 - 20 \log {}^{945}/_{50} = 83.9 - 25.5 = \underline{58.4}$

63.6 dBA

@ Receptor $\boxed{6}$

Ⓐ $86.1 - 20 \log {}^{820}/_{50} = 86.1 - 24.3 = 61.8$

Ⓑ $83.9 - 20 \log {}^{920}/_{50} = 83.9 - 25.3 = \underline{58.6}$

63.5 dBA

Construction Noise Model #C2

Month #3, peak @ Ⓑ

1.) No barriers

2.) @ site Center Ⓐ

		w/impact	w/o impact
1 Piledriver	@	91	omit
1 Jackhammer	@	81	
1 Pump	@	78	
2 Backhoes	@	77 × 2	same
2 Loaders	@	75 × 2	
1 Bulldozer	@	76	
1 Crane	@	75	
1 Paving Ripper	@	84	omit
1 concrete truck	@	82	same
SUBTOTAL		93.2	87.7

@ site Center Ⓑ

	w/ impact	w/o impact
1 piledriver	91	omit
1 pump	78	
1 Backhoe	77	
2 loaders	75 × 2	same
1 Bulldozer	76	
2 cranes	75 ×2	
1 truck	75	
SUBTOTAL	92.0	84.9

MODELC 2 (with impact devices)

© Receptor $\boxed{1}$

Ⓐ $93.2 - 20 \text{ LOG } {}^{550}/_{50} = 93.2 - 20.9 = 72.3$

Ⓑ $92.0 - 20 \text{ LOG } {}^{595}/_{50} = 92.0 - 21.5 = \underline{70.5}$

74.5 dBA

② Receptor $\boxed{2}$

Ⓐ $93.2 - 20 \text{ LOG } {}^{510}/_{50} = 93.2 - 20.2 = 73.0$

Ⓑ $92.0 - 20 \text{ LOG } {}^{355}/_{50} = 92.0 - 17.0 = \underline{75.0}$

77.1 dBA

@ Receptor $\boxed{3}$

Ⓐ $93.2 - 20 \text{ LOG } {}^{560}/_{50} = 93.2 - 21.0 = 72.2$

Ⓑ $92.0 - 20 \text{ LOG } {}^{680}/_{50} = 92.0 - 22.7 = \underline{69.3}$

74.0 dBA

@ Receptor $\boxed{4}$

Ⓐ $93.2 - 20 \text{ LOG } {}^{688}/_{50} = 93.2 - 22.8 = 70.4$

Ⓑ $92.0 - 20 \text{ LOG } {}^{840}/_{50} = 92.0 - 24.5 = \underline{67.5}$

72.2 dBA

@ Receptor $\boxed{5}$

Ⓐ $93.2 - 20 \text{ LOG } {}^{795}/_{50} = 93.2 - 24.0 = 69.2$

Ⓑ $92.0 - 20 \text{ LOG } {}^{945}/_{50} = 92.0 - 25.5 = \underline{66.5}$

71.1 dBA

@ Receptor $\boxed{6}$

Ⓐ $93.2 - 20 \text{ LOG } {}^{820}/_{50} = 93.2 - 24.3 = 68.9$

Ⓑ $92.0 - 20 \text{ LOG } {}^{920}/_{50} = 92.0 - 25.3 = \underline{66.7}$

70.9 dBA

MODEL C2 (without impact devices)

@ Receptor $\boxed{1}$

Ⓐ $87.7 - 20\ \mathrm{LOG}\ {}^{550}/_{50} = 87.7 - 20.9 = 66.8$

Ⓑ $84.9 - 20\ \mathrm{LOG}\ {}^{595}/_{50} = 84.9 - 21.5 = 63.4$

68.4 dBA

@ Receptor $\boxed{2}$

A $87.7 - 20\ \mathrm{LOG}\ {}^{510}/_{50} = 87.7 - 20.2 = 67.5$

B $84.9 - 20\ \mathrm{LOG}\ {}^{355}/_{50} = 84.9 - 17.0 = 67.9$

70.7 dBA

@ Receptor $\boxed{3}$

Ⓐ $87.7 - 20\ \mathrm{LOG}\ {}^{560}/_{50} = 87.7 - 21.0 = 66.7$

Ⓑ $84.9 - 20\ \mathrm{LOG}\ {}^{680}/_{50} = 84.9 - 22.7 = 62.2$

68.0 dBA

@ Receptor $\boxed{4}$

Ⓐ $87.7 - 20\ \mathrm{LOG}\ {}^{688}/_{50} = 87.7 - 22.8 = 64.9$

Ⓑ $84.9 - 20\ \mathrm{LOG}\ {}^{840}/_{50} = 84.9 - 24.5 = 60.4$

67.5 dBA

@ Receptor $\boxed{5}$

Ⓐ $87.7 - 20\ \mathrm{LOG}\ {}^{795}/_{50} = 87.7 - 24.0 = 63.7$

Ⓑ $84.9 - 20\ \mathrm{LOG}\ {}^{945}/_{50} = 84.9 - 25.5 = 59.4$

65.1 dBA

@ Receptor $\boxed{6}$

Ⓐ $87.7 - 20\ \mathrm{LOG}\ {}^{820}/_{50} = 87.7 - 24.3 = 63.4$

Ⓑ $84.9 - 20\ \mathrm{LOG}\ {}^{920}/_{50} = 84.9 - 25.3 = 59.6$

64.9 dBA

ction Noise Model C3

MONTH 13, Peak @ Ⓒ

) No Barriers

) Site Ⓐ

	with Impact	w/o Impact
Cherry Picker	78	78
SUBTOTAL	78	78

Site Ⓑ

	with Impact	w/o Impact
1 Truck	75	75
SUBTOTAL	75	75

Site Ⓒ

	with Impact	w/o Impact
3 piledrivers	91 x 3	omit
1 pump	78	same
1 backhoe	77	
1 loader	75	
1 bulldozer	76	
3 cranes	75 x 3	
1 truck	75	
1 concrete truck	82	
SUBTOTAL	96.3 dBA	86.7 dBA

Site Ⓓ

	with Impact	w/o Impact
2 pumps	78 x 2	SAME
2 cranes	75 x 2	
2 cherry-pickers	78 x 2	
1 truck	75	
1 concrete-truck	82	
2 fork-lifts	78 x 2	
2 mortar mixers	81 x 2	
1 concrete Pump	78	
SUBTOTAL	89.8	85.8

MODEL C3 (with impact devices)

L_{eq} @ Receptor $\boxed{1}$

Ⓐ 78 -20 LOG 555/50 = 78 -20.9 = 57.1

Ⓑ 75 - 20 LOG 595/50 = 75 -21.5 = 53.5

Ⓒ 96.3- 20 LOG 449/50 = 96.3 - 18.9 = 77.4

Ⓓ 89.8 - 20 LOG 630/50 = 89.8 - 22.0 = 67.8

Ⓔ ——————

77.9 dBA

L_{eq} @ Receptor $\boxed{2}$

Ⓐ 78 - 20 LOG 510/50 = 78 - 20.2 = 67.8

Ⓑ 75 - 20 LOG 355/50 = 75 -17.0 = 58.0

Ⓒ 96.3 - 20 LOG 1105/50 = 96.3 - 26.9 = 69.4

Ⓓ 89.3 - 20 LOG 820/50 = 89.3 - 24.3 = 65.5

Ⓔ ——————

= 72.8 dBA

L_{eq} @ Receptor $\boxed{3}$

Ⓐ 78 -20 LOG /50 = 78 -21.0 = 57.0

Ⓑ 75 - 20 LOG /50 = 75 - 22.7 = 52.3

Ⓒ 96.3 -20 LOG /50 = 96.3 -24.5 = 71.8

Ⓓ 89.3 -20 LOG /50 = 89.3 - 17.5 = 72.3

Ⓔ ——————

75.2 dBA

Model C3 (with impact devices) cont.

@ Receptor $\boxed{4}$

Ⓐ $78 - 20\ \mathrm{LOG}\ {}^{688}/_{50} = 78 - 22.8 = 55.2$

Ⓑ $75 - 20\ \mathrm{LOG}\ {}^{840}/_{50} = 75 - 24.5 = 50.5$

Ⓒ $96.3 - 20\ \mathrm{LOG}\ {}^{520}/_{50} = 96.3 - 20.3 = 76.0$

Ⓓ $89.8 - 20\ \mathrm{LOG}\ {}^{370}/_{50} = 89.8 - 17.4 = \underline{72.4}$

Ⓔ ———— 77.6 dBA

@ Receptor $\boxed{5}$

Ⓐ $78 - 20\ \mathrm{LOG}\ {}^{795}/_{50} = 78 - 24.0 = 54.0$

Ⓑ $75 - 20\ \mathrm{LOG}\ {}^{945}/_{50} = 75 - 25.5 = 49.5$

Ⓒ $96.3 - 20\ \mathrm{LOG}\ {}^{305}/_{50} = 96.3 - 15.7 = 80.6$

Ⓓ $89.8 - 20\ \mathrm{LOG}\ {}^{530}/_{50} = 89.8 - 20.5 = \underline{69.3}$

Ⓔ ———— 80.9 dBA

@ Receptor $\boxed{6}$

Ⓐ $78 - 20\ \mathrm{LOG}\ {}^{820}/_{50} = 78 - 24.3 = 53.7$

Ⓑ $75 - 20\ \mathrm{LOG}\ {}^{920}/_{50} = 75 - 25.3 = 49.7$

Ⓒ $96.3 - 20\ \mathrm{LOG}\ {}^{280}/_{50} = 96.3 - 15.0 = 81.3$

Ⓓ $89.8 - 20\ \mathrm{LOG}\ {}^{750}/_{50} = 89.8 - 23.5 = \underline{66.3}$

Ⓔ ———— 81.4 dBA

MODEL C3 (without impact devices)

Leq @ Receptor $\boxed{1}$

Ⓐ 78 - 20 LOG $^{555}/_{50}$ = 78 - 20.9 = 57.1

Ⓑ 75 - 20 LOG $^{595}/_{50}$ = 75 - 21.5 = 53.5

Ⓒ 86.7 - 20 LOG $^{449}/_{50}$ = 86.7 - 18.9 = 67.8

Ⓓ 89.8 - 20 LOG $^{632}/_{50}$ = 89.8 - 22.0 = $\underline{67.8}$

Ⓔ 71.1 dBA

Leq @ Receptor $\boxed{2}$

Ⓐ 78 - 20 LOG $^{510}/_{50}$ = 78 - 20.2 = 67.8

Ⓑ 75 - 20 LOG $^{355}/_{50}$ = 75 - 17.0 = 58.0

Ⓒ 86.7 - 20 LOG $^{1105}/_{50}$ = 86.7 - 26.9 = 59.8

Ⓓ 89.3 - 20 LOG $^{820}/_{50}$ = 89.3 - 24.3 = $\underline{65.5}$

Ⓔ ———— 70.5 dBA

Leq @ Receptor $\boxed{3}$

Ⓐ 78 - 20 LOG /50 = 78 - 21.0 = 57.0

Ⓑ 75 - 20 LOG /50 = 75 - 22.7 = 52.3

Ⓒ 86.7 - 20 LOG /50 = 86.7 - 24.5 = 62.2

Ⓓ 89.3 - 20 LOG /50 = 89.3 - 17.5 = $\underline{72.3}$

Ⓔ ———— 72.9 dBA

Model C3 (without impact devices) cont.

@ Receptor $\boxed{4}$

(A) 78 -20 LOG 688/50 = 78 -22.8 = 55.2

(B) 75 - 20 LOG 840/50 = 75 - 24.5 = 50.5

(C) 86.7 - 20 LOG 520/50 = 86.7 - 20.3 = 66.4

(D) 89.8 -20 LOG 370/50 = 89.8 - 17.4 = 72.4

(E) —

73.5 dBA

@ Receptor $\boxed{5}$

(A) 78 -20 LOG 795/50 = 78 -24.0 = 54.0

(B) 75 -20 LOG 945/50 = 75 -25.5 = 49.5

(C) 86.7 -20 LOG 305/50 = 86.7 -15.7 = 71.0

(D) 89.8 -20 LOG 530/50 = 89.8 -20.5 = 69.3

(E) ———

73.3 dBA

@ Receptor $\boxed{6}$

(A) 78 - 20 LOG 820/50 = 78 -24.3 = 53.7

(B) 75 - 20 LOG 920/50 = 75 -25.3 = 49.7

(C) 86.7 - 20 LOG 280/50 = 86.7 -15.0 = 71.7

(D) 89.8 - 20 LOG 750/50 = 89.8 - 23.5 = 66.3

(E) ———

72.9 dBA

Construction Noise Model C4

Month #23, Peak @ Ⓒ

1.) Luxury Hotel superstructure provides partial barrier on triangle. Assume 5 dB reduction where line of site is broken by triangle.

2.) @ Site Ⓑ - Leq

2	cranes	75 × 2
1	truck	75
1	concrete truck	82
2	hoists	80 × 2
2	forklifts	78 × 2
2	mortar mixers	~~8~~ 81 × 2
	SUBTOTAL	89.2

no imp
devic
use
any
site c

Leq @ Site Ⓒ

5	cranes	75 × 5
1	cherry picker	78
1	truck	75
2	concrete trucks	82 × 2
4	hoists	80 × 4
4	forklifts	78 × 4
4	mortar mixers	81 × 4
2	concrete pumps	78 × 2
	SUBTOTAL	92.7

MODEL C4 continued

Leq @ site Ⓓ

6	cranes	75	×6
2	cherry pickers	78	× 2
1	truck	75	
1	paver	80	
1	compactor	74	
4	forklifts	78	×4
4	mortar mixers	81	× 4
2	concrete pumps	78	× 2
	SUBTOTAL	89.9	

MODEL #C4 (No impact devices inuse during

Leq @ Receptor $\boxed{1}$

Ⓐ ______

Ⓑ 89.2 − 20 LOG $^{595}/_{50}$ = 89.2 − 21.5 = 67.7

Ⓒ 92.7 − 20 LOG $^{449}/_{50}$ = 92.7 − 18.9 = 73.8

Ⓓ 89.9 − 20 LOG $^{630}/_{50}$ = 89.9 − 22.0 = 67.9

Ⓔ ______

75.6 dBA

Leq @ Receptor $\boxed{2}$

Ⓐ ______

Ⓑ 89.2 − 20 LOG $^{355}/_{50}$ = 89.2 − 17.0 = 72.2

Ⓒ 92.7 − 20 LOG $^{1105}/_{50}$ = 92.7 − 26.9 = 65.8

Ⓓ 89.9 − 20 LOG $^{820}/_{50}$ = 89.9 − 24.3 = 65.6

Ⓔ ______

73.8 − 5dBA

68.8

Leq @ Receptor $\boxed{3}$

Ⓐ ______

Ⓑ 89.2 − 20 LOG /50 = 89.2 − 22.7 = 66.5

Ⓒ 92.7 − 20 LOG /50 = 92.7 − 24.5 = 68.2

Ⓓ 89.9 − 20 LOG /50 = 89.9 − 17.5 = 72.4

Ⓔ ______

74.5 dB

Model C4 cont.

@ Receptor $\boxed{4}$

Ⓐ ________

Ⓑ 89.2 - 20 LOG $^{840}/_{50}$ = 89.2 - 24.5 = 64.7

Ⓒ 92.7 - 20 LOG $^{520}/_{50}$ = 92.7 - 20.3 = 70.4

Ⓓ 89.9 - 20 LOG $^{370}/_{50}$ = 89.9 - 17.4 = 72.5

Ⓕ ________ 75.0 dBA

@ Receptor $\boxed{5}$

Ⓐ ________

Ⓑ 89.2 - 20 LOG $^{945}/_{50}$ = 89.2 - 25.5 = 63.7

Ⓒ 92.7 - 20 LOG $^{305}/_{50}$ = 92.7 - 15.7 = 77.0

Ⓓ 89.9 - 20 LOG $^{530}/_{50}$ = 89.9 - 20.5 = 69.4

Ⓔ ________ 77.9 dBA

@ Receptor $\boxed{6}$

Ⓐ ________

Ⓑ 89.2 - 20 LOG $^{920}/_{50}$ = 89.2 - 25.3 = 63.9

Ⓒ 92.7 - 20 LOG $^{280}/_{50}$ = 92.7 - 15.0 = 77.7

Ⓓ 89.9 - 20 LOG $^{750}/_{50}$ = 89.9 - 23.5 = 66.4

78.2 dBA

Ⓔ ________

construction Noise Model C5

MONTH #11, Peak @ Ⓓ

1.) No barriers

2) Leq @ Ⓐ	w/impact	w/o impac
1 compressor	81	same
1 pump	78	
1 backhoe	77	
1 Loader	75	
1 bulldozer	76	
1 paving ripper	84	omit
1 cherry picker	78	same
SUBTOTAL	88.4	83.9
Leq @ Ⓑ		
1 crane	75	75
SUBTOTAL	75	75
Leq @ Ⓒ		
1 pile driver	91	omit
1 pump	78	same
1 backhoe	77	
2 loaders	75 x2	
1 bulldozer	76	
1 truck	75	
SUBTOTAL	91.8	83.9

MODEL C5 (with impact devices)

-eq @ Receptor $\boxed{1}$

Ⓐ $88.4 - 20 \text{ LOG } {}^{555}/_{50} = 88.4 - 20.9 = 63.0$

Ⓑ $75 - 20 \text{ LOG } {}^{595}/_{50} = 75 - 21.5 = 53.5$

Ⓒ $91.8 - 20 \text{ LOG } {}^{449}/_{50} = 91.8 - 18.9 = 72.9$

Ⓓ $97.4 - 20 \text{ LOG } {}^{630}/_{50} = 97.4 - 22.0 = \underline{75.4}$

77.8 dBA

Ⓔ ———

-eq @ Recepter $\boxed{2}$

Ⓐ $88.4 - 20 \text{ LOG } {}^{510}/_{50} = 88.4 - 20.2 = 68.2$

Ⓑ $75 - 20 \text{ LOG } {}^{355}/_{50} = 75 - 17.0 = 58.0$

Ⓒ $91.8 - 20 \text{ LOG } {}^{1105}/_{50} = 91.8 - 26.9 = 64.9$

Ⓓ $97.4 - 20 \text{ LOG } {}^{820}/_{50} = 97.4 - 24.3 = \underline{73.1}$

74.9 dBA

Ⓔ ———

eq @ Receptor $\boxed{3}$

Ⓐ $88.4 - 20 \text{ LOG } /50 = 88.4 - 21.0 = 67.4$

Ⓑ $75 - 20 \text{ LOG } /50 = 75 - 22.7 = 52.3$

Ⓒ $91.8 - 20 \text{ LOG } /50 = 91.8 - 24.5 = 67.3$

Ⓓ $97.4 - 20 \text{ LOG } /50 = 97.4 - 17.5 = \underline{79.9}$

80.4 dBA

Ⓔ ———

Model C5 (with impact devices)

Leq @ Receptor $\boxed{4}$

Ⓐ 88.4 − 20 LOG 688/50 = 88.4 − 22.8 = 65.6

Ⓑ 75 − 20 LOG 840/50 = 75 − 24.5 = 50.5

Ⓒ 91.8 − 20 LOG 520/50 = 91.8 − 20.3 = 71.5

Ⓓ 97.4 − 20 LOG 370/50 = 97.4 − 17.4 = 80.0

Ⓔ ______

80.7 dBA

eq @ Receptor $\boxed{5}$

Ⓐ 88.4 − 20 LOG 745/50 = 88.4 − 24.0 = 64.4

Ⓑ 75 − 20 LOG 945/50 = 75 − 25.5 = 49.5

Ⓒ 91.8 − 20 LOG 305/50 = 91.8 − 15.7 = 76.1

Ⓓ 97.4 − 20 LOG 530/50 = 97.4 − 20.5 = 76.9

Ⓔ ______

79.7 dB

q @ Receptor $\boxed{6}$

Ⓐ 88.4 − 20 LOG 820/50 = 88.4 − 24.3 = 64.1

Ⓑ 75 − 20 LOG 920/50 = 75 − 25.3 = 49.7

Ⓒ 91.8 − 20 LOG 285/50 = 91.8 − 15.0 = 76.8

Ⓓ 97.4 − 20 LOG 750/50 = 97.4 − 23.5 = 72.9

Ⓔ ______

78.5

MODEL C5 (without impact devices)

eq @ Receptor $\boxed{1}$

Ⓐ 83.9 − 20 LOG $^{555}/50$ = 83.9 − 20.9 = 63.0

Ⓑ 75 − 20 LOG $^{595}/50$ = 75 − 21.5 = 53.5

Ⓒ 83.9 − 20 LOG $^{449}/50$ = 83.9 − 18.9 = 65.0

Ⓓ 86.8 − 20 LOG $^{630}/50$ = 86.8 − 22.0 = 64.8

Ⓔ ———— 69.2 dBA

eq @ Receptor $\boxed{2}$

Ⓐ 83.9 − 20 LOG $^{510}/50$ = 83.9 − 20.2 = 63.7

Ⓑ 75 − 20 LOG $^{355}/50$ = 75 − 17.0 = 58.0

Ⓒ 83.9 − 20 LOG $^{1105}/50$ = 83.9 − 26.9 = 57.0

Ⓓ 86.8 − 20 LOG $^{820}/50$ = 86.8 − 24.3 = 62.5

Ⓔ ———— 67.2 dBA

eq @ Receptor $\boxed{3}$

Ⓐ 83.9 − 20 LOG /50 = 83.9 − 21.0 = 62.9

Ⓑ 75 − 20 LOG /50 = 75 − 22.7 = 52.3

Ⓒ 83.9 − 20 LOG /50 = 83.9 − 24.5 = 59.4

Ⓓ 86.8 − 20 LOG /50 = 86.8 − 17.5 = 69.3

Ⓔ ———— 70.6 dBA

Model C5 (without impact devices) Ci

L_{eq} @ Receptor $\boxed{4}$

Ⓐ $83.9 - 20 \text{ LOG } {}^{688}/_{50} = 83.9 - 22.8 = 61.1$

Ⓑ $75 - 20 \text{ LOG } {}^{8410}/_{50} = 75 - 24.5 = 50.5$

Ⓒ $83.9 - 20 \text{ LOG } {}^{520}/_{50} = 83.9 - 20.3 = 63.6$

Ⓓ $86.8 - 20 \text{ LOG } {}^{370}/_{50} = 86.8 - 17.4 = \underline{69.4}$

Ⓔ ——— 70.9 dBA

L_{eq} @ Receptor $\boxed{5}$

Ⓐ $83.9 - 20 \text{ LOG } {}^{795}/_{50} = 83.9 - 24.0 = 59.9$

Ⓑ $75 - 20 \text{ LOG } {}^{945}/_{50} = 75 - 25.5 = 49.5$

Ⓒ $83.9 - 20 \text{ LOG } {}^{305}/_{50} = 83.9 - 15.7 = 68.2$

Ⓓ $86.8 - 20 \text{ LOG } {}^{530}/_{50} = 86.8 - 20.5 = \underline{66.3}$

70.8 dBA

Ⓔ — ——

L_{eq} @ Receptor $\boxed{6}$

Ⓐ $83.9 - 20 \text{ LOG } {}^{820}/_{50} = 83.9 - 24.3 = 59.6$

Ⓑ $75 - 20 \text{ LOG } {}^{920}/_{50} = 75 - 25.3 = 49.7$

Ⓒ $83.9 - 20 \text{ LOG } {}^{280}/_{50} = 83.9 - 15.0 = 68.9$

Ⓓ $86.8 - 20 \text{ LOG } {}^{750}/_{50} = 86.8 - 23.5 = \underline{63.3}$

Ⓔ ——— : 70.4 dB

Construction Noise Model C6

MONTH 28, Peak @ Ⓔ

) Barrier accross all of site. Assume 5dBA reduction for all sites except E on [redacted] Harcourt & Tent City; D on Tent City.

) Leq @ Ⓐ ————

Leq @ Ⓑ

	with impact	w/o impact
2 cranes	75 x2	same
1 truck	75	
2 hoists	80 x2	
2 forklifts	78 x2	
2 mortarmixers	81 x2	
SUBTOTAL	88.3	88.3

Leq @ Ⓒ

4 cranes	75 x4	same
1 truck	75	
1 concrete truck	82	
4 hoists	80 x4	
2 forklifts	78 x2	
2 mortar mixers	81 x 2	
1 concrete pump	78	
SUBTOTAL	90.6	90.6

MODEL C6, continued

Leq @ Ⓓ

		w/impact	w/o imp
7	cranes	75	sam
2	cherry pickers	78	
1	truck	75	
1	concrete truck	82	
4	fork lifts	78	
2	mortar mixers	81	
3	concrete pumps	78	
	SUBTOTAL	90.9	90.9

Leq @ Ⓔ

1	pile driver	91	omit
1	compressor	81	same
1	backhoe	77	
1	loader	75	
		91.7	83.2

MODEL C6 (with impact devices)

Leq @ Receptor $\boxed{1}$

Ⓐ ———

Ⓑ 88.3 − 20 LOG $^{595}/50$ = 88.3 − 21.5 = 66.8

Ⓒ 90.6 − 20 LOG $^{449}/50$ = 90.6 − 18.9 = 71.7

Ⓓ 90.9 − 20 LOG $^{630}/50$ = 90.9 − 22.0 = 68.9

Ⓔ 91.7 − 20 LOG $^{795}/50$ = 91.7 − 24.0 = 67.7

75.2 − 5 = 70.2 dBA

Leq @ Receptor $\boxed{2}$

Ⓐ ———

Ⓑ 88.3 − 20 LOG $^{355}/50$ = 88.3 − 17.0 = 71.3

Ⓒ 90.6 − 20 LOG $^{1105}/50$ = 90.6 − 26.9 = 63.7

Ⓓ 90.9 − 20 LOG $^{820}/50$ = 90.9 − 24.3 = 66.6

Ⓔ 91.7 − 20 LOG $^{1295}/50$ = 91.7 − 28.3 = 63.4

73.5 − 5 = 68.5

eq @ Receptor $\boxed{3}$

Ⓐ ———

Ⓑ 88.3 − 20 LOG /50 = 88.3 − 22.7 = 65.6 − 5 = 60.6

Ⓒ 90.6 − 20 LOG /50 = 90.6 − 24.5 = 66.1 − 5 = 61.1

Ⓓ 90.9 − 20 LOG /50 = 90.9 − 17.5 = 73.4 = 73.4

Ⓔ 91.7 − 20 LOG $^{685}/50$ = 91.7 − 22.7 = 60.5 − 5 = 55.5

74.4 dBA

Model C6 (with impact devices) c

Leq @ Receptor $\boxed{4}$

Ⓐ ———

Ⓑ 88.3 - 20 LOG $^{840}/50$ = 88.3 - 24.5 = 63.8 - 5 = 58.

Ⓒ 90.6 - 20 LOG $^{520}/50$ = 90.6 - 20.3 = 70.3 - 5 = 65.

Ⓓ 90.9 - 20 LOG $^{370}/50$ = 90.9 - 17.4 = 73.5

Ⓔ 91.7 - 20 LOG $^{230}/50$ = 91.7 - 13.3 = 78.4

79.8 dBA

Leq @ Receptor $\boxed{5}$

Ⓐ ———

Ⓑ 88.3 - 20 LOG $^{945}/50$ = 88.3 - 25.5 = 62.8 - 5 = 57.8

Ⓒ 90.6 - 20 LOG $^{305}/50$ = 90.6 - 15.7 = 74.9 - 5 = 69.

Ⓓ 90.9 - 20 LOG $^{530}/50$ = 90.9 - 20.5 = 70.4 - 5 = 65

Ⓔ 91.7 - 20 LOG $^{104}/50$ = 91.7 - 6.4 = 85

85.5

Leq @ Receptor $\boxed{6}$

Ⓐ ———

Ⓑ 88.3 - 20 LOG $^{920}/50$ = 88.3 - 25.3 = 63.0

Ⓒ 90.6 - 20 LOG $^{280}/50$ = 90.6 - 15.0 = 75.6

Ⓓ 90.9 - 20 LOG $^{750}/50$ = 90.9 - 23.5 = 67.4

Ⓔ 91.7 - 20 LOG $^{635}/50$ = 91.7 - 22.1 = 69.6

77.2 - 5 = 72.

MODEL C6 (without impact devices)

-eq @ Receptor $\boxed{1}$

Ⓐ ———

Ⓑ 88.3 - 20 LOG $^{595}/50$ = 88.3 - 21.5 = 66.8

Ⓒ 90.6 - 20 LOG $^{449}/50$ = 90.6 - 18.9 = 71.7

Ⓓ 90.9 - 20 LOG $^{630}/50$ = 90.9 - 22.0 = 68.9

Ⓔ 83.2 - 20 LOG $^{795}/50$ = 83.2 - 24.0 = 59.2

74.5 - 5 = 69.5 dBA

-eq @ Receptor $\boxed{2}$

Ⓐ ——

Ⓑ 88.3 - 20 LOG $^{355}/50$ = 88.3 - 17.0 = 71.3

Ⓒ 90.6 - 20 LOG $^{1105}/50$ = 90.6 - 26.9 = 63.7

Ⓓ 90.9 - 20 LOG $^{820}/50$ = 90.9 - 24.3 = 66.6

Ⓔ 83.2 - 20 LOG $^{1295}/50$ = 83.2 - 28.3 = 54.9

73.2 - 5 = 68.2 dBA

-eq @ Receptor $\boxed{3}$

Ⓐ ———

Ⓑ 88.3 - 20 LOG /50 = 88.3 - 22.7 = 65.6 - 5 = 60.6

Ⓒ 90.6 - 20 LOG /50 = 90.6 - 24.5 = 66.1 - 5 = 61.1

Ⓓ 90.9 - 20 LOG /50 = 90.9 - 17.5 = 73.4 = 78.4

Ⓔ 83.2 - 20 LOG $^{685}/50$ = 83.2 - 22.7 = 60.5 - 5 = 55.5

74.4 dBA

Model C6 (without impact devices) C

Leq @ Receptor [4]

(A) ———

(B) 88.3 - 20 LOG 840/50 = 88.3 - 24.5 = 63.8 - 5 = 58.8

(C) 90.6 - 20 LOG 520/50 = 90.6 - 20.3 = 70.3 - 5 = 65.3

(D) 90.9 - 20 LOG [illegible]/50 = 90.9 - 17.4 = 73.5

(E) 83.2 - 20 LOG 230/50 = 83.2 - 13.3 = 69.9

75.6 dB

Leq @ Receptor [5]

(A) ———

(B) 88.3 - 20 LOG 945/50 = 88.3 - 25.5 = 62.8 - 5 = 57.

(C) 90.6 - 20 LOG 305/50 = 90.6 - 15.7 = 74.9 - 5 = 69.

(D) 90.9 - 20 LOG 530/50 = 90.9 - 20.5 = 70.4 - 5 = 65

(E) 83.2 - 20 LOG 104/50 = 83.2 - 6.4 = 76.8

77.9 dB

Leq @ Receptor [6]

(A) ———

(B) 88.3 - 20 LOG [illegible]/50 = 88.3 - 25.3 = 63.0

(C) 90.6 - 20 LOG [illegible]/50 = 90.6 - 15.0 = 75.6

(D) 90.9 - 20 LOG [illegible]/50 = 90.9 - 23.5 = 67.4

(E) 83.2 - 20 LOG 635/50 = 83.2 - 22.1 = 61.1

76.5 - 5 = 71.

TABLE OF DISTANCES & CORRECTION FACTORS

A to	1	– 555'	$20 \log {}^{555}/_{50} = 20.9$
	2	510	= 20.2
	3	560	= 21.0
	4	688	= 22.8
	5	795	= 24.0
	6	820	= 24.3
B to	1	595	→ 21.5
	2	355	→ 17.0
	3	680	→ 22.7
	4	840	→ 24.5
	5	945	→ 25.5
	6	920	→ 25.3
C to	1	440	→ 18.9
	2	1105	→ 26.9
	3	840	→ 24.5
	4	520	→ 20.3
	5	305	→ 15.7
	6	280	→ 15.0

20 log d/d₀

D to 1 630 → 22.0
2 820 → 24.3
3 375 → 17.5
4 370 → 17.4
5 530 → 20.5
6 750 → 23.5

E to 1 795 → 24.0
2 1295 → 28.3
3 685 → 22.7
4 230 → 13.3
5 104 → 6.4
6 635 → 22.1

APPENDIX H

FUTURE-CASE TRAFFIC MODELS

NOISE MODEL 1

FUTURE CASE

model #1
point source
future

NAME
DATE
PROJECT

				LINK 18					
				A	MT	HT	A	MT	HT
1	Lane No./Road Segment								
2	Vehicle Class								
3.	N (vph)			90	45	45			
4	S (kph)				50*				
5	D (m)				61				
6	ϕ_1 (degrees)	FIG 5							
7	ϕ_2 (degrees)	FIG 5							
8.	$(L_o)E_i$ (dBA)	FIG 2		62.3	74.0	80.3			
9	10 LOG $(N_i D_o/S_i)$ dB	FIG 3		14.3	11.3	11.3			
a.	20 LOG (D_o/D) dBA	FIG 4			-12.2				
b.	15 LOG (D_o/D) dBA	FIG 4							
a.	10 LOG $(\Psi_o(\phi_1, \phi_2)/\pi)$	FIG 6							
b.	10 LOG $(\Psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7							
2.	ϕ_L (degrees)	FIG 10							
3.	ϕ_R (degrees)	FIG 10							
4.	δ_o (m)	FIG 9							
5.	N_o	EQ 18							
6.	Δ_B (dBA)	App B							
7.	CONSTANT (dB)				-25				
8.	Leq(h) (dBA)			39.4	48.1	54.4			
9.	Leq(h) dBA			—	55.4	—			
0.	Δ_s dBA	FIG 8							
1.	Leq(h) dBA								
2.	Leq(h) dBA								
3.	ND/S (m/km)								
4.	$(L_{10} - L_{eq})_i$ dBA	FIG 15							
5.	L_{10} (h) dBA								
6.	L_{10} (h) dBA								
7.	L_{10} (h) dBA								

NAME
DATE
PROJECT

			LINK 6			LINK 11		
			A	MT	HT	A	NT	H
1.	Lane No./Road Segment							
2.	Vehicle Class							
3.	N (vph)		1186	167	42	115[illegible]	[illegible]	[illegible]
4.	S (kph)			50*			50*	
5.	D (m)		/	188	/	/	134	/
6.	ϕ_1 (degrees)	FIG 5	/	-5	/	/	-5	/
7.	ϕ_2 (degrees)	FIG 5	/	+10	/	/	-10	/
8.	$(L_o)E_i$ (dBA)	FIG 2	[illegible]	74.0	[illegible]	[illegible]	[illegible]	[illegible]
9.	$10 \log (N_i D_o / S_i)$ dB	FIG 3	25.6	17.0	11.0	25.6	17.0	11.[illegible]
10a.	$10 \log (D_o/D)$ dBA	FIG 4	/	/	/	/	/	/
10b.	$15 \log (D_o/D)$ dBA	FIG 4		-13.7			-14.[illegible]	
11a.	$10 \log (\psi_o(\phi_1,\phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	$10 \log (\psi_{1/2}(\phi_1,\phi_2)/\pi)$	FIG 7		-11			-11	
12.	ϕ_L (degrees)	FIG 10						
13.	ϕ_R (degrees)	FIG 10						
14.	δ_o (m)	FIG 9						
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-25
18.	Leq(h) (dBA)		[illegible]	41.3	41.6	37.6	40.[illegible]	[illegible]
19.	Leq(h) dBA		/	45.4	/	/	44.8	/
20.	Δ_s dBA	FIG 8						
21.	Leq(h) dBA							
22.	Leq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10} - Leq)_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated da
* = Minimum 50 km/

MODEL 2 FUTURE CASE

NAME
DATE
PROJECT 020

Lane No./Road Sagmant		Link 1						
Vahicla Class		A	MT	HT	A	NT	HT	
N (vph)		689	97	24				P/E
S (kph)			50*					P
D (m)		/	135	/	/		/	M
ϕ_1 (dagraas)	FIG 5	/	-47	/	/		/	Es
ϕ_2 (dagreas)	FIG 5	/	-25	/	/		/	Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3				
10 LOG $(N_i D_o / S_i)$ dB	FIG 3	23.1	14.6	8.6				
10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/	/	
15 LOG (D_o/D) dBA	FIG 4		-14.3					
10 LOG $(\psi_o(\phi_1,\phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
10 LOG $(\psi_{12}(\phi_1,\phi_2)/\pi)$	FIG 7		-9.4					
ϕ_L (degraas)	FIG 10							
ϕ_R (dagraes)	FIG 10							
δ_o (m)	FIG 9							
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		36.7	39.9	40.2				
Leq(h) dBA		/	44.0	/	/		/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10} - L_{eq})_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

MODEL [illegible]

NAME
DATE
PROJECT

			LINK [illegible]			LINK [illegible]		
1.	Lane No./Road Segment							
2.	Vehicle Class		A	MT	HT	A	MT	HT
3.	N (vph)		1186	167	-12	1186	[illegible]	[illegible]
4.	S (kph)			50*			50	
5.	D (m)		/	[illegible]	/	/	[illegible]	/
6.	Φ_1 (degrees)	FIG 5	/	[illegible]	/	/	[illegible]	/
7.	Φ_2 (degrees)	FIG 5	/	[illegible]	/	/	[illegible]	/
8.	$(L_o)Ei$ (dBA)	FIG 2	[illegible]	[illegible]	[illegible]	[illegible]		
9.	10 LOG $(N_i D_o/S_i)$ dB	FIG 3	[illegible]	[illegible]	11.0	[illegible]	[illegible]	11.
10a.	10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/	/
10b.	15 LOG (D_o/D) dBA	FIG 4		-4.7			[illegible]	
11a.	10 LOG $(\Psi_o(\Phi_1,\Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	10 LOG $(\Psi_{1/2}(\Phi_1,\Phi_2)/\pi)$	FIG 7		-10.2			[illegible]	
12.	Φ_L (degrees)	FIG 10						
13.	Φ_R (degrees)	FIG 10						
14.	δ_o (m)	FIG 9						
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-25
18.	Leq(h) (dBA)		45.	[illegible]	46.4	[illegible]	[illegible]	[illegible]
19.	Leq(h) dBA		/	503	/	/	[illegible]	/
20.	Δ_s dBA	FIG 8						
21.	Leq(h) dBA							
22.	Leq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10}-Leq)_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km/

FUTURE NOISE MODEL 2

model 2 future case

NAME
DATE
PROJECT 020

Lane No. /Road Sagment		point source Link 10			Link 11			
Vahicle Class		A	MT	HT	A	NT	HT	
N (vph)		2188	309	77	1186	167	42	P/E
S (kph)			50*			50*		P
D (m)		/	167	/	/	55	/	M
ϕ_1 (dagraas)	FIB 5	/	—	/	/	-60	/	Es
Φ_2 (dagraas)	FIG 5	/	—	/	/	+70	/	Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	62.3	74.0	80.3	
$10 \log (N_i D_o / S_i)$ dB	FIG 3	25.2	19.7	13.6	25.5	17.0	11.0	
$10 \log (D_o/D)$ dBA	FIG 4	/	/	/	/	/	/	
$15 \log (D_o/D)$ dBA	FIG 4		-20.9			-8.5		
$10 \log (\Psi_o(\phi_1, \phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
$10 \log (\Psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7		—			-2.0		
ϕ_L (degraas)	FIG 10							
ϕ_R (dagraas)	FIG 10							
δ_o (m)	FIG 9		45.9			55.[illegible]		
No	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		44.6	47.8	48.0	52.3	55.5	55.8	
Leq(h) dBA		/	51.8	/	/	59.6	/	
Δ_s dBA	FIG 8							
Laq(h) dBA								
Laq(h) dBA								
ND/S (m/km)								
$(L_{10}-L_{aq})_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated data
* = Minimum 50 km/h

NAME
DATE
PROJECT

COPLEY MODEL 2
FUTURE CASE:

			LINK 16			LINK 17		
1.	Lane No./Road Segment							
2.	Vehicle Class		A	MT	HT	A	NT	HT
3.	N (vph)		796	112	28	398	56	14
4.	S (kph)			50*			50*	
5.	D (m)		/	30	/	/	64	/
6.	ϕ_1 (degrees)	FIG 5	/	-75	/	/	-45	/
7.	ϕ_2 (degrees)	FIG 5	/	+40	/	/	+5	/
8.	$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3	62.3	74.0	80.3
9.	$10 \log (N_i D_o / S_i)$ dB	FIG 3	23.8	15.3	9.2	20.8	12.3	6.2
10a.	$10 \log (D_o/D)$ dBA	FIG 4	/	/	/	/	/	/
10b.	$15 \log (D_o/D)$ dBA	FIG 4		-4.5			-9.5	
11a.	$10 \log (\Psi_o(\phi_1, \phi_2)/\pi)$	FIG 6	/	/	/	/	/	/
11b.	$10 \log (\Psi_{1/2}(\phi_1, \phi_2)/\pi)$	FIG 7		-25			-58	
12.	ϕ_L (degrees)	FIG 10						
13.	ϕ_R (degrees)	FIG 10						
14.	δ_o (m)	FIG 9		32			40.3	
15.	N_o	EQ 18						
16.	Δ_B (dBA)	App B						
17.	CONSTANT (dB)		-25	-25	-25	-25	-25	-25
18.	Leq(h) (dBA)		54.1	57.3	57.5	42.8	46.0	46.2
19.	Leq(h) dBA		/	61.3	/	/	500	/
20.	Δ_s dBA	FIG 8						
21.	Leq(h) dBA							
22.	Leq(h) dBA							
23.	ND/S (m/km)							
24.	$(L_{10} - L_{eq})_i$ dBA	FIG 15						
25.	L_{10} (h) dBA							
26.	L_{10} (h) dBA							
27.	L_{10} (h) dBA							

A = assumed
P = Parsons data
M = Measured data
E = ERT data
E_s = Estimated dat
* = Minimum 50 km/

future case
model 6

NAME
DATE
PROJECT 020

Lane No./Road Segment		LINK 18						
Vehicle Class		A	MT	HT	A	NT	HT	
N (vph)		90	45	45				P/E
S (kph)			50*					P
D (m)		/	119	/	/		/	M
Φ_1 (degrees)	FIG 5	/	-55	/	/		/	Es
Φ_2 (degrees)	FIG 5	/	-30	/	/		/	Es
$(L_o)E_i$ (dBA)	FIG 2	62.3	74.0	80.3				
10 LOG $(N_i D_o/S_i)$ dB	FIG 3	14.3	11.3	11.3				
a. 10 LOG (D_o/D) dBA	FIG 4	/	/	/	/	/	/	
b. 15 LOG (D_o/D) dBA	FIG 4		-13.5					
a. 10 LOG $(\Psi_o(\Phi_1,\Phi_2)/\pi)$	FIG 6	/	/	/	/	/	/	
b. 10 LOG $(\Psi_{1/2}(\Phi_1,\Phi_2)/\pi)$	FIG 7		-9.0					
Φ_L (degrees)	FIG 10							
Φ_R (degrees)	FIG 10							
δ_o (m)	FIG 9		47.5					
N_o	EQ 18							
Δ_B (dBA)	App B							
CONSTANT (dB)		-25	-25	-25	-25	-25	-25	
Leq(h) (dBA)		29.1	37.8	44.1				
Leq(h) dBA		/	45.1	/	/		/	
Δ_s dBA	FIG 8							
Leq(h) dBA								
Leq(h) dBA								
ND/S (m/km)								
$(L_{10}-Leq)_i$ dBA	FIG 15							
L_{10} (h) dBA								
L_{10} (h) dBA								
L_{10} (h) dBA								

Link 18 - modal split =

.50 A
.25 MT
.25 HT

A = assumed
P = Parsons data
M = Measured data
E = ERT data
Es = Estimated data
* = Minimum 50 km/h

APPENDIX I

HVAC EQUIPMENT MODEL

VENT FAN SCENARIO

Assume each fan is 54 dB @ 100'

LOCATION		FAN SCHEME
A	57.0	2 fans*, venting upward, release @ 23' 57.0 use 2 × 54 dBA @ 100' 57.0
B	57.0	2 fans, release @ 183' 57.0
C	64.4	10 fans, release @ 183' 64.4 dB
D	–	Gas exhaust, no fans
E	57.0	57.0 2 fans*, release point 10' above grade
F	57.0	57.0 2 fans*, release point 7 stories (~80' above grade)
G	61.8	[illegible] fans forming [illegible] stack 61.8 assume 200' above grade
H	57.0	2 fans, intake @ ~ 150' 57.0
I	57.0	57.0 2 fans* assume 10' above grade
J	—	No fans

* assumed in the absence of design data

Table of Distances - meters

Vent	Receptor 1	2	3	4	5	6
A	198	337	177	69	64	177
B	181	323	187	91	73	157
C	134	226	172	157	171	186
D	102	187	216	213	216	189
E	250	264	55	120	198	285
F	258	384	174	35	67	223
G	116	229	189	166	171	171
H	233	317	114	46	119	235
I	142	165	189	210	233	227
J	175	366	247	131	52	116

Barrier Adjustments

	1	2	3	4	5	6
A	-5	-10	-5	0	0	-5
B	-10	-10	-5	0	0	-5
C	0	-5	-5	-10	-10	-5
E	-10	-10	0	-10	-5	-10
F	-5	-10	0	0	0	-10
G	0	-10	-5	-10	-10	-5
H	-10	-10	0	0	-5	-10
I	-5	-10	-5	-10	-10	0
J	-10	-10	-10	-10	0	0

DISTANCE (AND BARRIER) ADJUSTMENTS

			Receptors			
IT	1	2	3	4	5	6
	16(-5)	21(-10)	15(-5)	7	6	15(-5)
	15(-10)	20(-10)	16(-5)	9	8	14(-5)
	13	17(-5)	15(-5)	14(-10)	15(-10)	16(-5)
	10	16	17	17	17	16
	18(-10)	19(-10)	5	12(-10)	16(-5)	19(-10)
	17(-5)	22(-10)	15	1	7	17(-10)
	12	18(-10)	16(-5)	15(-10)	15(-10)	15(-5)
	18(-10)	20(-10)	11	4	12(-5)	18(-10)
	13(-5)	15(-10)	16(-5)	17(-10)	18(-10)	17
	15(-10)	22(-10)	18(-10)	13(-10)	5	11

Property of
BOSTON REDEVELOPMENT AUTHORITY
Library

BACK BAY H112A.N
(Copley Pl.)

H M M Associates, Inc.

Copley Place Noise
Levels Report.

BACK BAY H112A.N
(Copley Pl.)

BOSTON REDEVELOPMENT AUTHORITY
Property of
Library

Universal™
office products

Report Binder
Stock No./Color

80571	Black
80572	Lt. Blue
80573	Dk. Blue
80578	Rust
80579	Exec. Red

MADE IN THE USA